EDISON AND HIS FIRST HAND-TURNED PHONOGRAPH.

MODERN WONDER WORKERS

A Popular History of American Invention

EDITED BY

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WITH OVER THREE HUNDRED ILLUSTRATIONS

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PART I

THE REVOLUTION OF TRANSPORTATION

CHAPTER I

FROM STEPHENSON TO THE TWENTIETH CENTURY LIMITED —THE STORY OF AMERICAN RAILROADING

BEFORE the invention of the railway, the principal manufacturing towns both of Great Britain and the United States were situated on or near the coast-line or navigable streams. This was natural enough, for in the development of commerce sailing vessels were the chief, and perhaps the only, progressive means of transportation. Inland, goods and foodstuffs had to be carried or hauled over the wretched roads.

According to Lardner, the eminent British historian of the early nineteenth century, "the internal transport of goods in England was performed by wagon, and was not only intolerably slow, but so expensive as to exclude every object except manufactured articles, and such as—being of light weight and small bulk in proportion to their value—would allow of a high rate of transport." Lardner found that the charge for carriage by wagon from London to Leeds was at the rate of about $63.31 a ton, being 27 cents per ton-mile. Between Liverpool and Manchester it was $9.60 a ton, or 30 cents per ton-mile. "Heavy materials such as coal could only be available for commerce where their position favored transport by sea, and consequently, many of the richest districts of the kingdom remained unproductive, awaiting the tardy advancement of the art of transport." Not until 1833 was a daily mail established between London and Paris, and the charge on foreign letters, in addition to the ship's postage and the expense in foreign countries, varied from twenty-eight to eighty-four cents. The postage on a letter sent from one point in England to another amounted to about twenty cents a sheet. Hence letters were usually intrusted to some person bound for the city in which the addressee lived.

Bad as they were in England, conditions in the American colonies were worse. Here the roads were nothing but trails,

thick with dust in summer, heavy with mud in winter, often completely impassable, and deviating miles out of the way to avoid a mountain or river. As late as 1780 the roadways of Pennsylvania were still narrow paths which had been made through the woods by Indians and traders. Brissot de Warville, a Frenchman who travelled in the United States in 1788, thus describes part of a journey which he took from Philadelphia to Baltimore:

"From thence (Havre de Grace) to Baltimore are reckoned sixty miles. The road in general is frightful; it is over a clay soil, full of deep ruts, always in the midst of forests, frequently obstructed by trees overset by the wind, which obliged us to seek a new passage through the woods. I cannot conceive why the stage does not often overset. Both the drivers and their horses discover great skill and dexterity, being accustomed to these roads."

Such were most of the roads of the United States even for many years after the founding of the Republic. The only reasonably good roads were those connecting the principal towns. On the maps of 1800 only a few roads are shown in northern New England, northern and western New York, northwestern Pennsylvania, and in the South; there are none in eastern Maine. The South was particularly indifferent to the condition of its roads, probably because the plantations were situated on the banks of rivers, making it easy to market produce by boat. So rich a region as that along the Susquehanna was cut off from the outer world up to 1786. One of the reasons urged for the removal of the State capital from Philadelphia to Harrisburg, in 1799, was the cost of travel, which bore heavily on the legislators. In a country with few roads carriages and wagons were, therefore, seen chiefly in the cities. Before the Revolution a man travelled by horse or by boat—preferably by boat.

As the population increased, turnpike and stage-coach companies were organized, but it was not until 1783 that Levi Pease started the first stage-coach line between Boston and New York. Washington died on December 14, 1799, and it took ten days for the news of such an important event to reach Boston by stage-coach. Two days was the usual time in which this lumbering vehicle covered the distance between New York and

Philadelphia, although the road was the best in the country—an engineering masterpiece of wood resting on mud or "on a soil that trembled when stepped upon." And the stage-coach itself was not the imposing carriage which we associate with Mr. Pickwick's journeys or our modern fashionable four-in-hands; it was an open wagon, with curtains which could be raised or lowered, and it contained four benches to accommodate twelve miserable passengers.

Little wonder that, when possible, most Americans preferred to travel by water in the more roomy sloops. All the towns along the Atlantic seaboard from Boston to New York were connected by these sailing vessels. The fare from Providence to New York by sloop was six dollars. Meals, however, were charged for at such high rates that their cost for the trip exceeded the fare.

Without roads, industry remained at a standstill. Wilbert Lee Anderson in his *Country Town* states that "merchandise and produce that could not stand a freight charge of fifteen dollars a ton could not be carried overland to a consumer 150 miles from the point of production." Hence each State was its own producer, and also its own consumer. Nearly every American in Washington's time who did not live near a town raised his own wool and flax, did his own spinning and weaving, and made his own clothing. It cost twenty dollars to haul a cord twenty miles, and five dollars to haul a barrel of flour 150 miles. So great were transportation charges that every community had to be more or less self-supporting.

In less than a century all this was changed. The United States was transformed from a wilderness of forest and prairie into a land of active industry; this astonishing transformation is due chiefly to the invention of the locomotive engine and its development to meet American conditions.

The American Railway Track

The steam locomotive is so much more picturesque than the track on which it runs that in most histories of invention scant attention has been paid to the road-bed. A house has its foundations, and a locomotive must have its tracks. Indeed, without the track there would be no locomotive.

Have you ever ridden a bicycle over a fine, new, concrete road and suddenly passed on to a stretch of worn-out country road? On the concrete you were spinning along with little effort at twelve to fifteen miles an hour; now your machine begins to bump and crash among the holes and loose rocks; you labor hard, but your speed drops to six or eight miles. The reason for this is that instead of moving along on a smooth and level line you are now lifting your weight over a series of obstacles. This takes more leg power. If you were the size of a small beetle crawling across the road, and a wagon looked proportionately big to you, its wheels rolling over the rough surface would appear to be alternately climbing hills and dropping into valleys, as it crashed noisily by. If you asked the driver of the wagon, he would tell you that he could haul five times as great a load on the smooth concrete as he could on the country road, with its humps and hollows, rocks, sand, and mud.

One-half of the success of the steam railroad is due to those two shining strips of smooth, hard, and unyielding steel rail, securely held in place upon broad, solid ties and the broken-stone road-bed.

For the first attempt to build tracks for loaded vehicles, we must go back several centuries—the sixteenth-century days of coal-mining in England. The loaded coal-carts were heavy, the roads were poor, and the wheels cut deep ruts in them. Eventually the miners laid heavy planks in the bottom of the ruts, and at once found the going much easier for the horses. Then they laid crosspieces, or "ties," as we now call them, along the roads, and upon them fastened longitudinal timbers. This was better, but the wood surface of the "tramway" did not last long. Some one suggested in the eighteenth century that flat strips of iron be spiked down on the timbers. For many, many years thereafter tracks were so laid. But the iron wore away the wooden wheels of the little wagons, so that early in the eighteenth century iron wheels were substituted. Sometimes in place of wood granite blocks were used, about eight inches square and five feet long, laid end to end, and on these, toward the close of the eighteenth century, the flat strips of iron, or "plates," were fastened. In England the men who lay rails are still called "plate-layers."

The first railway to be built in America was of this character. It was particularly constructed to bring heavy blocks of granite from the Quincy quarries to Boston for the Bunker Hill Monument. The line, three miles long, was opened in 1828, and a granite monument, standing alongside the New Haven tracks,

Courtesy of the Pennsylvania Railroad.

THE STONE BLOCKS USED BY THE PHILADELPHIA AND COLUMBIA RAILWAY.

Part of the road-bed of the Old Portage Railroad near Gallitzin, Pa. Frost split and even shifted the stone blocks, and the rails were consequently twisted out of place.

six miles south of Boston, marks the site of this first American wagon railroad. It was a crude piece of work, yet it taught the American people of that day how vastly superior was an iron track for transporting heavy freight.

A railroad track, however, must possess a certain amount of spring or elasticity, and it was found that granite was too rigid. The concussion of the iron wheels of the loaded wagons worked loose the rails, especially at the ends, and it was realized that granite was not the thing to use.

In 1789 William Jessop introduced in England the system of fastening cast-iron "chairs," or sockets, to the sleepers, and of securing the rails in the chairs. It was Jessop, too, who invented the modern flanged wheel—that is, a wheel with a rim on the inside to prevent it from slipping from the track. He is also credited with having fixed the gauge of to-day—four feet eight and one-half inches.

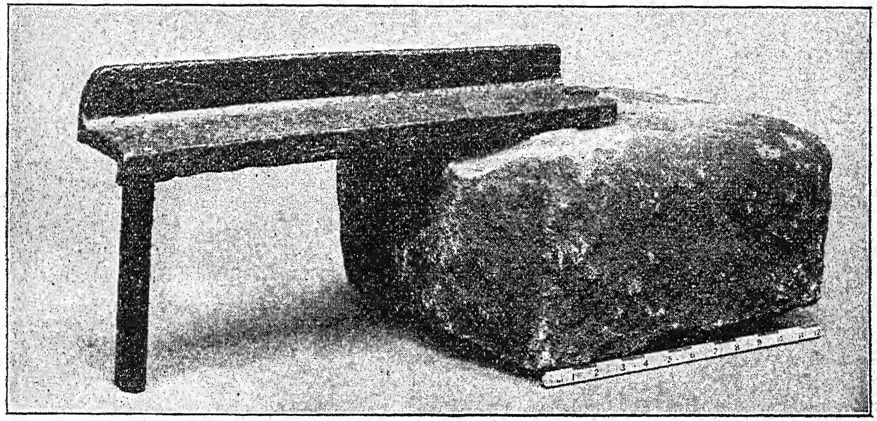
What appears to have been most difficult was the construction of a track foundation that would remain stable. As late as 1841 the president of the Erie Railroad ordered piles driven for one hundred miles on dry land to provide a substantial support for the stringers and rails. The expedient failed. There was no elasticity to the structure, and it was pounded to destruction by the heavy trains. Then came cross-ties.

Of course on early American railroads, as on those in England, the hauling was done by horses. David Stevenson, who came to this country about 1836 to study our railways, wrote: "I travelled by horse-power on the Mohawk and Hudson Railway from Schenectady to Albany, a distance of sixteen miles, and the journey was performed in sixty-five minutes, being at the astonishing rate of fifteen miles an hour. The car by which I was conveyed carried twelve passengers, and was drawn by two horses, which ran stages of five miles." Clearly, the old horse-cars were not so slow as might be supposed.

The first American railroad to be constructed with the intention of using steam locomotives only, was the South Carolina Railroad, commenced in 1827; but the first road to be opened was the Baltimore and Ohio, which was partly put in operation for service in 1830. Their first rail was laid on July 4, 1828, by Charles Carroll, of Carrollton, the only then surviving signer of the Declaration of Independence.

The promoters of the Baltimore and Ohio decided to build a model railroad, and they sent their engineers to England to report on the roads of that country. Acting upon the report submitted, the use of granite was still retained, and a track was built, consisting of granite sills, eight by fifteen inches in lengths of six to ten feet. These rested on broken stone ballast, laid in two parallel trenches, and the flat iron strips of rail, five-eighths of an inch thick and two and one-half inches wide,

were spiked into wooden plugs inserted in holes drilled in the granite. Mr. Hasell Wilson, one of the best of the American engineers of that day, said of this track: "It was an entire failure; it was found impracticable to maintain an even surface; the track spread apart; and the iron rails worked loose, causing frequent accidents." It was the fond hope of the early railway-builders that they could construct a road to last forever, and to this end it was thought that a substance like granite was ab-



Courtesy of the South Kensington Museum.

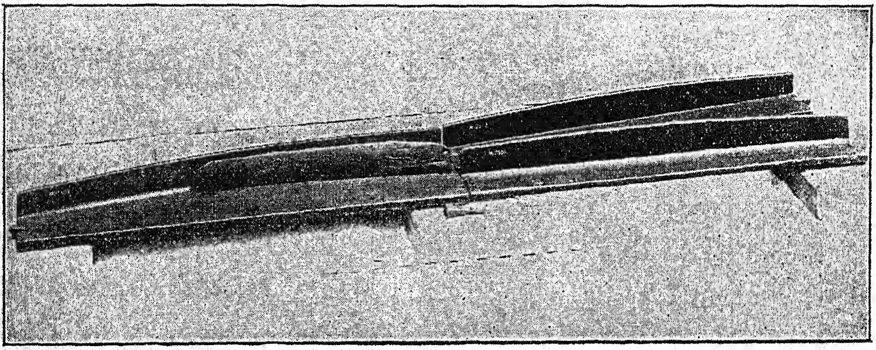
PLATE-RAIL AND STONE SLEEPER, SURREY IRON RAILWAY, 1804.

solutely necessary. But frost split and even shifted the stone blocks, and the rails were consequently twisted out of place. Experiment followed experiment; all without success.

But the pioneers were not daunted. On the line in course of construction between Philadelphia and Columbia, 163 miles of single track, they tried three different systems. Six miles were laid with granite sills, as on the Baltimore and Ohio; eighteen miles with wood instead of granite sills; and the remainder with stone blocks, eighteen inches square, placed three feet apart. On these stone blocks they laid "edge-rails," so called because the flanged wheel ran on the upper edge of the rail. They were from nine to fifteen feet long, and had been imported from England.

Early iron rails were of two kinds: the plate-rail and the edge-rail. The plate-rail was L-shaped. The wheels ran on the

flat base of the L, and were prevented by the vertical flange from running off the track. The edge-rail also had a flat base, but from the centre of it projected a vertical flange. The wheel ran on the top of this flange. With this rail, however, although it was stiffer and more serviceable than the plate-rail, it was necessary to have a projecting flange on the wheels. At first the flange was on the outside of the wheel; later Jessop put it on the inside, and in that position it has remained ever since.



Courtesy of the South Kensington Museum.

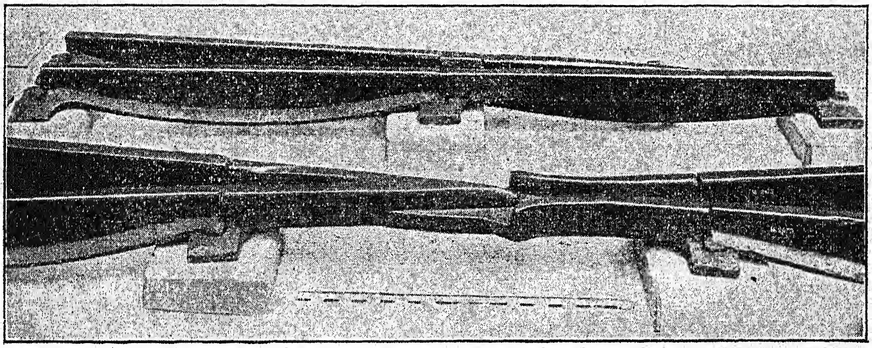
PLATE-RAIL OF THE TICKNALL TRAMWAY IN ENGLAND.

This tramway was constructed in 1799 by Benjamin Outram. A line 4.25 miles in length connected with the Ashby Canal, Leicestershire. It is still occasionally used. The metals are of cast iron and are of angled section, the raised flange being arranged on the inside of the track. The switch shown has a wrought-iron tongue, provided with a stem which drops into a hole into the casting, but no mechanical device is provided for moving the tongue.

The railway was now utterly dependent on the iron-maker. Not until the founder learned how to roll rails that would endure could railway travel be safe and speedy. It was a great advance when wrought iron was substituted for cast iron, an innovation that followed the patenting, in 1820, of a method of rolling wrought-iron rails by John Birkinsaw, who operated the Bedington Iron Works, of Durham, England. George Stephenson used Birkinsaw's rails on the famous Stockton and Darlington road, and also on the Liverpool and Manchester.

The edge-rail and the inside-flange wheel led to the system which is in use to-day. A remarkable American, Robert Livingston Stevens, the son of Colonel John Stevens, was the inventor of this system, and its principal feature is the T-rail. While

Stevens was on his way to Europe, in 1830, to order for the Camden and Amboy Railroad the locomotive that has passed into history as the "John Bull," he thought much about tracks and their defects. Out of wood he whittled models of rails, one of which was the forerunner of the modern broad-based T-rail, so called from its cross-section, and it was eventually laid by Stevens himself on the Camden and Amboy Railroad. The rail-rollers of England thought Stevens a "crank." He had



Courtesy of the South Kensington Museum.

JESSOP EDGE-RAILS.

These rails were laid down by William Jessop in 1789. This is believed to have been a first instance of a narrow rail being used on its edge, and therefore marks a great advance upon the earlier wooden ways and plate ways.

to assume full responsibility for failure, pay all extra expenses, and to put up a bond to pay for any damages that might be inflicted on the rail works. Although regarded as a dangerous innovation, the T-rail was in use on many roads by 1840. Stevens's rail had a wide, flat base, by which it was secured to the tie with hooked spikes. It weighed thirty-six pounds to the yard. To-day, rails weigh from ninety to 130 pounds.

The early rails of America were of British manufacture, and were often carried as ship ballast. By removing the duty on railroad iron the government made it possible to lay the rails down in New York at a cost not much greater than the English purchase price. It was largely for this reason that we did not roll our own rails until about 1840. When we began to roll rails of steel, something like perfection was attained. A steel

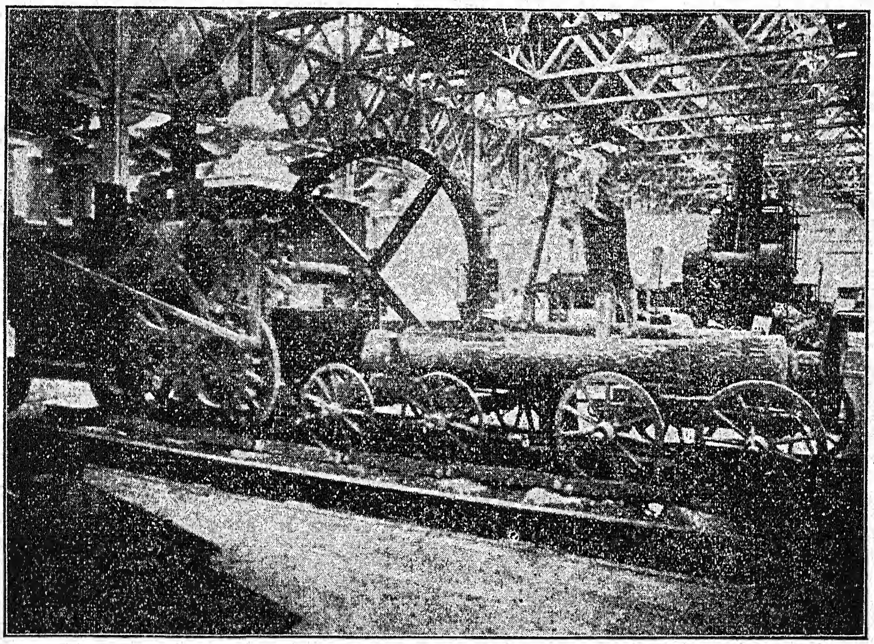
rail is from eight to fifteen times more durable than one made of iron, and is much less liable to break. In the chapter on iron and steel the development of this rail is more fully described. "Probably no other single influence was so effective in reducing the cost of transportation and improving the general conditions of the railroads as the substitution of steel for iron rails." This is the verdict of Bogart in his *Economic History of the United States*.

It was the steel rail that brought the Western wheat-growing regions into direct competition with the agricultural industry of the East; consequently it soon had a profound effect on farming in the British Isles. After it was introduced railroad companies began to move passengers and freight at a minimum expense. The steel rail has, therefore, been the principal factor in enabling the American railroad to populate the West by distributing the hordes that migrated from Europe.

A road-bed must be well drained. This is secured by finishing the surface of the natural ground (the subgrade) with a slight slope from the centre to the sides, so that rain-water, passing through the ballast, will run off into the side ditches. On the subgrade are laid about eighteen inches of broken stone, upon which are laid the cross-ties, preferably of oak. The ballast is frequently filled up flush with the top of the ties, and banked up against their ends. By this means a firm and yet elastic foundation is provided. To increase the bearing surface, steel tie-plates are inserted between the base of the rails and the ties, and the hooked spikes pass through square holes in these plates, and thus enable the spikes to offer resistance to any lateral spreading of the rail. The abutting ends of the rails are held in true alignment and level by two splice-bars or angle-bars, one on each side of the joint, which are held against the rail by four or six bolts. The ties are spread about two feet, centre to centre, the two ties at each joint being brought closer together, to afford additional support at this, the weakest point in the rail. The heaviest rails to-day are of 130 pounds to the yard on certain sections of the Pennsylvania Railroad, and 135-pound rails are being experimented with on the Lackawanna road.

The Invention and Introduction of the Locomotive

As soon as the great James Watt had perfected the steam-engine, it occurred to many practical men that here was a machine which would supersede horses for hauling loads on tramways. The first of these seems to have been the Cornishman, Richard Trevithick, who was born in 1771, and died penniless in 1833. Trevithick, a giant of a man, who could beat the



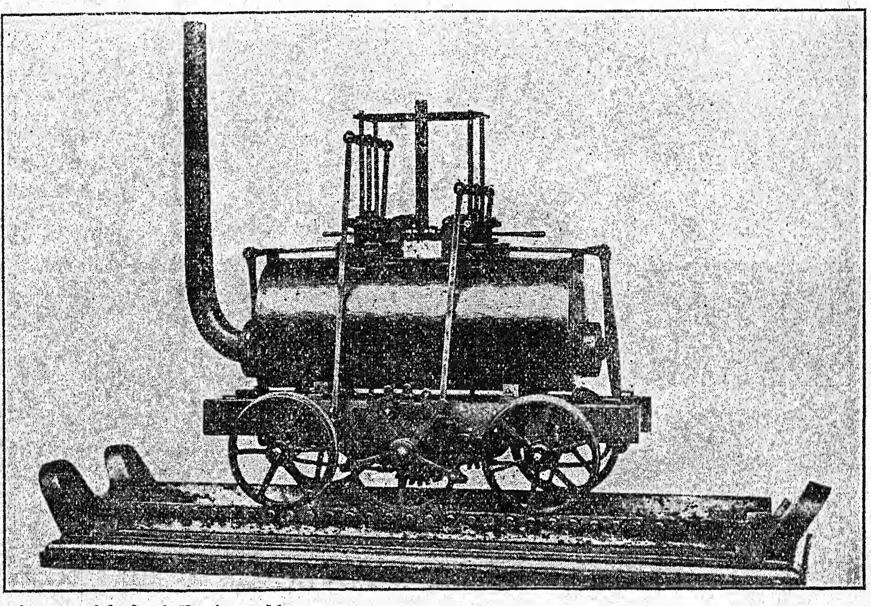
Courtesy of the Baltimore and Ohio Railroad.

MODEL OF TREVITHICK'S LOCOMOTIVE OF 1804.

whole countryside in wrestling and feats of strength, was so capable an inventor that he must be regarded as one of the originators of the modern automobile, although he used steam instead of gasoline as the propelling power. He was one of Watt's few formidable and successful rivals in the development of the steam-engine, although there is good reason to believe that he saw the earlier plans for such an engine drawn by Oliver Evans.

Too much credit cannot be given to the American, Oliver

Evans, for his conception of a locomotive engine. In the chapter on the steam-engine his engineering skill has been sufficiently dwelt upon, and some of the more important events of his embittered life have been noted. Horatio Allen, who imported and ran the first locomotive in America, said that his engine had



Courtesy of the South Kensington Museum.

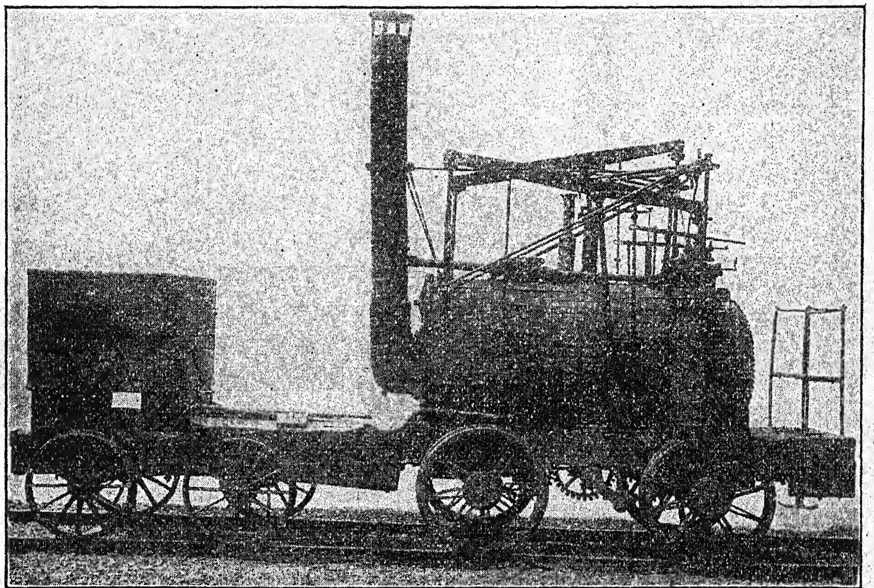
BLENKINSOP'S LOCOMOTIVE, PATENTED IN 1811.

A racked or tooth rail was laid alongside the road; into this rack the toothed wheel of the locomotive worked. The engine had two cylinders, an innovation due to Matthew Murray, of Leeds. The connecting-rods gave motion to two pinions by cranks at right angles to each other; these pinions communicating the motion to the wheel which engaged the rack. Blenkinsop's engines began running in 1812, and were the first to be regularly engaged for commercial purposes.

all the elements of a permanent success. "Had Evans a Boulton, as Watt had a co-operating Boulton . . . the high-pressure steam-engine would have had a position from that time of great interest to the country, and, through this country to the world." Evans was probably the first to invent the multitubular boiler, now a distinguishing feature of the locomotive, although his was a water-tube and not a fire-tube boiler.

After he had built and operated half a dozen "road locomo-

tives," or steam automobiles, Trevithick, in 1804, built a real steam locomotive that ran on rails and hauled twenty tons of iron ore in Wales. Although horse-power was cheaper than steam for such work, he not only built another locomotive for a coal-mine, but also constructed a little circular passenger-



Courtesy of the South Kensington Museum.

THE "PUFFING BILLY" LOCOMOTIVE.

The "Puffing Billy" locomotive was constructed at Wylam colliery in 1813 by William Hedley, assisted by the enginewrights, one of whom, Timothy Hackworth, subsequently became locomotive superintendent of the Stockton and Darlington Railway. It worked between the colliery and the Staithes at Lennington-on-Tyne. The boiler is a wrought-iron cylinder with one egg end and has an internal return furnace flue as used by Trevithick. The engine usually hauled about fifty tons at a speed of five miles an hour. The fender consists of a wooden frame supported on four wheels, carrying a water-tank and coal-box.

railway near Euston Square, London, which attracted the curiosity and interest of many people.

Trevithick, in his turn, had some aggressive competitors. In 1811 John Blenkinsop built a coal-hauling locomotive that propelled itself by a cog, which engaged a rack attached to the tramway. Then there was William Hedley, whose "Puffing Billy" and "Wylam Dilly," built in 1813, also hauled coal.

But the foremost of all these pioneers and the man to whom

the modern railroad owes most was George Stephenson (who was born in 1781, and died in 1848). His was the typical career of an inventor, except that he amassed a fortune by the exercise of more business sense than that displayed by most inventors. After working as a cowherd and driving a gin-horse for a coal-mine, he became a pumping-engine attendant. A boy of seventeen, naturally imaginative and inventive, could hardly be brought face to face with Watt's great engine without wanting to fathom its mysteries. There were books enough on steam-engines, but he could not read. So he went to night-school, learned his letters, and then read about engines to his heart's content. From then on, his life was devoted to the steam-engine. He was so fascinated by Hedley's experiments with "Puffing Billy" that he induced the owners of the Killingsworth colliery to authorize him to build a locomotive which was to run on a railroad between the mine and a shipping port, nine miles distant. His first engine, the "Blucher," drew eight loaded wagons weighing thirty tons up a grade which rose one foot in every 450 feet.

Stephenson became engineer of the Stockton and Darlington Railway, authorized by Parliament in 1821. Horses were to be used for hauling the cars, but Stephenson successfully urged the adoption of steam locomotives. The line, thirty-eight miles long, was opened in 1825, with Stephenson driving an engine that hauled thirty-four tiny wagons or cars, constituting a load of ninety tons. A man on horseback rode in advance of the train, and on the easiest section of the line he had to gallop at the rate of fifteen miles an hour to keep in front.

Although the Stockton and Darlington Railway was built primarily as a freight road, there was such a demand for passenger accommodation that the company soon made arrangements to run a daily coach with six seats inside and fifteen outside. The "Experiment," as this first passenger-car was called, was little more than an ordinary stage-coach with iron wheels running on iron rails.

It might be supposed that after the Stockton and Darlington success England was prepared for a revolution in transportation. Far-sighted men were convinced that the steam road was destined to carry goods and people with undreamed-of

swiftness. On the other hand, conservative opinion pointed out, and very properly, that the engines lacked power and were expensive. A bookkeeper by a simple comparison of cost of horses and engines could easily dispose of any arguments in favor of steam. Allied to this objection was the opposition of the stage-coach lines, the canal companies, and the landed gentry, who resented the invasion of their estates by the smoking, roaring locomotives and their noisy trains of cars. In fact the charter of the Liverpool and Manchester road was obtained only with difficulty. It cost Huskisson, a skilled politician, seventy thousand pounds to carry it through.

The construction of this Liverpool and Manchester line was the turning-point. It was destined to prove, slowly but surely, the advantages of steam over horse-power, and the national benefits that would result from a smoothly operated steam railroad.

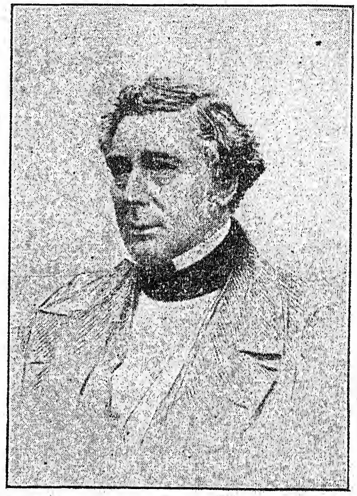
George Stephenson, his Stockton and Darlington experiences behind him, was engaged to build it. There were many obstacles in his path. To begin with, differences of opinion as to the tractive power to be employed sprang up amongst the officials. Some of them were in favor of the old, reliable horse, others advocated the use of fixed engines which could haul the cars by cables; in fact the best engineering opinion of the day was in favor of these fixed engines. George Stephenson, however, insisted upon steam locomotives.

Urging the merits of the locomotive at every opportunity, he pointed out the serious inconvenience that would arise to the whole line if one of the fixed engines should break down, and he dwelt on the large amount of capital that would have to be sunk in hauling-engines and engine-houses. If the locomotive was not yet economical it was because inventors had not been given sufficient encouragement, he argued. Great improvements could be made. He offered to build a locomotive himself which would haul heavy loads with speed, regularity, and safety. This persistence and earnestness led the directors to offer a prize of £500 for the best engine that would haul six tons at ten miles an hour, or twenty tons at ten miles, with a pressure of steam on the boiler not exceeding fifty pounds to the square inch. There were other conditions, not immoderate as we

look back at them now, but considered hopelessly difficult of fulfilment in 1830.

With the assistance of his son Robert, George Stephenson built a locomotive called the "Rocket." In his earliest engines Stephenson had used the system of exhausting the spent steam into the smoke-stack. Thus he found that the draft was in-

GEORGE STEPHENSON.



ROBERT STEPHENSON.

Foremost of the railway pioneers was George Stephenson, who was born in 1781 and died in 1848. As an illiterate pumping-engine attendant of seventeen, he learned how to read in order that he might be able to familiarize himself with principles of steam-engine construction as they were disclosed in books of the day. With him really begins the development of the modern locomotive.

Robert Stephenson assisted his distinguished father, George, in building the famous "Rocket" locomotive that won the Rainhill contest. He was born in 1803 and died in 1859. Unlike his father, he was a highly educated engineer. He built the London and Birmingham Railway, the first to run into London. He was even more distinguished as a civil than as a mechanical engineer.

creased, with the result that a hotter fire could be maintained under the boiler. The steam-blast was so essential to the generation of high-pressure steam that Stephenson used it in the "Rocket." To meet the conditions of the prize offer he had to provide a very large heating surface. He decided to adopt what we now call a multitubular boiler in which the fire was carried through a great many small tubes surrounded by water, rather than through the usual single flue. The idea was old, although Stephenson did not know it.

The complete "Rocket" had two cylinders, eight inches in diameter by sixteen and one-half inches stroke, direct-connected to driving-wheels measuring four feet eight inches in diameter, which were placed in front below the smoke-stack. The engine weighed four and one-quarter tons and the tender three and one-fifth tons. The steam pressure was fifty pounds.

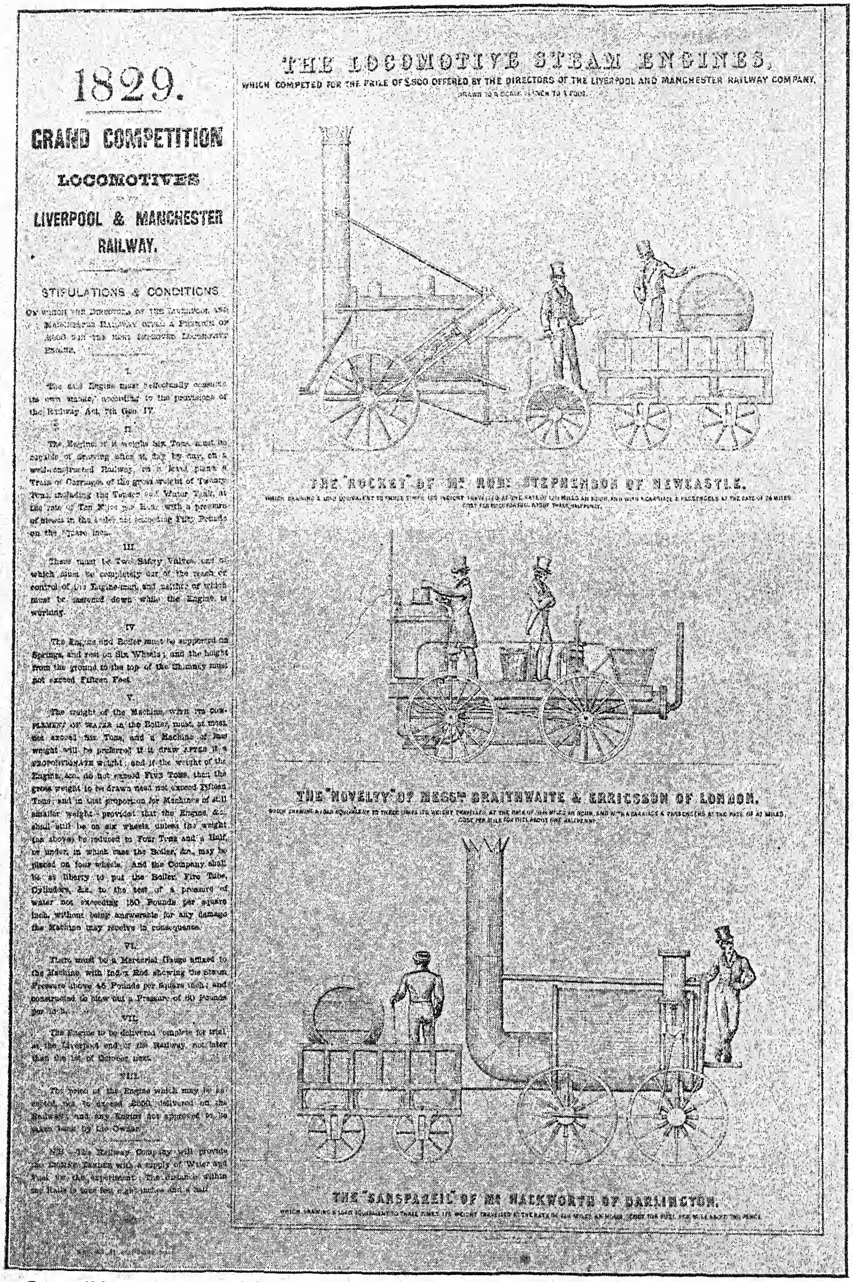
On the day when the great competition for the prize was to be held four locomotives were on hand. One was the "Rocket." Another was the "Novelty," designed by Ericsson, who was later destined to play a part in our Civil War as the builder of the *Monitor*. There were also Hackworth's "Sanspareil," and Burstall's "Perseverance."

Samuel Smiles, who knew Robert Stephenson, thus describes the contest in his *Life of George Stephenson and of His Son, Robert Stephenson:*

"The contest was postponed until the following day (October 7); but before the judges arrived on the ground the bellows for creating the draft in the 'Novelty' gave way, and it was found incapable of going through its performance. A defect was also found in the boiler of the 'Sanspareil,' and some further time was allowed to get it repaired. The large number of spectators who had assembled to witness the contest were greatly disappointed at this postponement; but to lessen it Stephenson brought out the 'Rocket,' and attaching it to a coach containing thirty persons, he ran them along at the rate of from twenty-four to thirty miles an hour, much to their gratification and amazement. Before separating, the judges ordered the engine to be in readiness by eight o'clock on the following morning, to go through its definite trial according to the prescribed conditions."

On the next day the "Rocket" surpassed all expectations. "It was the simple but admirable contrivance of the steam-blast and its combination with the multitubular boiler," says Smiles, "that at once gave locomotion a vigorous life and secured the triumph of the railway system."

But the railroad engineers were poor prophets. After Stephenson's dramatic success they confidently predicted immediate speeds of seventy-five and even a hundred miles an hour. On the other hand, they failed to appreciate the steam



1829.

GRAND COMPETITION

LOCOMOTIVES

LIVERPOOL & MANCHESTER RAILWAY.

STIPULATIONS & CONDITIONS

On which the Directors of the Liverpool and Manchester Railway offer a Premium of £500 for the most improved Locomotive Engine.

I.

The said Engine must effectually consume its own smoke, according to the provisions of the Railway Act, 7th Geo. IV.

II.

The Engine, if it weighs Six Tons, must be capable of drawing after it, day by day, on a well-constructed Railway, on a level plane, a Train of Carriages of the gross weight of Twenty Tons, including the Tender and Water Tank, at the rate of Ten Miles per Hour, with a pressure of steam in the boiler not exceeding Fifty Pounds on the Square Inch.

III.

There must be Two Safety Valves, one of which must be completely out of the reach or control of the Engine-man, and neither of which must be fastened down while the Engine is working.

IV.

The Engine and Boiler must be supported on Springs, and rest on Six Wheels; and the height from the ground to the top of the Chimney must not exceed Fifteen Feet.

V.

The weight of the Machine, with its complement of water in the Boiler, must, at most, not exceed Six Tons, and a Machine of less weight will be preferred if it draw after it a proportionate weight; and if the weight of the Engine, &c., do not exceed Five Tons, then the gross weight to be drawn need not exceed Fifteen Tons; and in that proportion for Machines of still smaller weight—provided that the Engine, &c., shall still be on six wheels, unless the weight (as above) be reduced to Four Tons and a Half, or under, in which case the Boiler, &c., may be placed on four wheels. And the Company shall be at liberty to put the Boiler, Fire Tube, Cylinders, &c., to the test of a pressure of water not exceeding 150 Pounds per square inch, without being answerable for any damage the Machine may receive in consequence.

VI.

There must be a Mercurial Gauge affixed to the Machine, with Index Rod showing the Steam Pressure above 45 Pounds per Square inch; and constructed to blow out a Pressure of 60 Pounds per inch.

VII.

The Engine to be delivered complete for trial at the Liverpool end of the Railway, not later than the 1st of October next.

VIII.

The price of the Engine which may be accepted, not to exceed £550, delivered on the Railway; and any Engine not approved to be taken back by the Owner.

N.B.—The Railway Company will provide the Engine Tender with a supply of Water and Fuel for the experiment. The distance within the Rails is four feet eight inches and a half.

THE LOCOMOTIVE STEAM ENGINES,

WHICH COMPETED FOR THE PRIZE OF £500 OFFERED BY THE DIRECTORS OF THE LIVERPOOL AND MANCHESTER RAILWAY COMPANY.

DRAWN TO A SCALE OF 1 INCH TO A FOOT.

THE "ROCKET" OF Mr. ROBt. STEPHENSON OF NEWCASTLE.

THE "NOVELTY" OF MESSrs. BRAITHWAITE & ERRICSSON OF LONDON.

THE "SANSPAREIL" OF Mr. HACKWORTH OF DARLINGTON.

From a lithograph, courtesy of the South Kensington Museum.

THREE LOCOMOTIVE ENGINES WHICH COMPETED AT RAINHILL IN 1829.

This is an announcement of the prize of £500 offered by the Liverpool and Manchester Railway for the engine which would best fulfil its conditions.

locomotive's ability to haul great weights cheaply. Nor did they realize that the railroad could successfully compete with the waterway.

The "Rocket" is regarded as the forerunner of the modern locomotive because it had the following four modern fundamental elements of efficiency:

1. The fire-box was surrounded by the water of the boiler.

2. The boiler was horizontal, and the hot gases were led from the fire-box to the smoke-box through tubes which passed through the boiler, and which were surrounded by the water to be heated.

3. The steam exhausted into the smoke-stack, thereby greatly increasing the draft and making a very hot fire.

4. The power of the steam was exerted through the piston-rods and connecting-rods directly upon the driving-wheels, to which the connecting-rods were attached without any intervening parts.

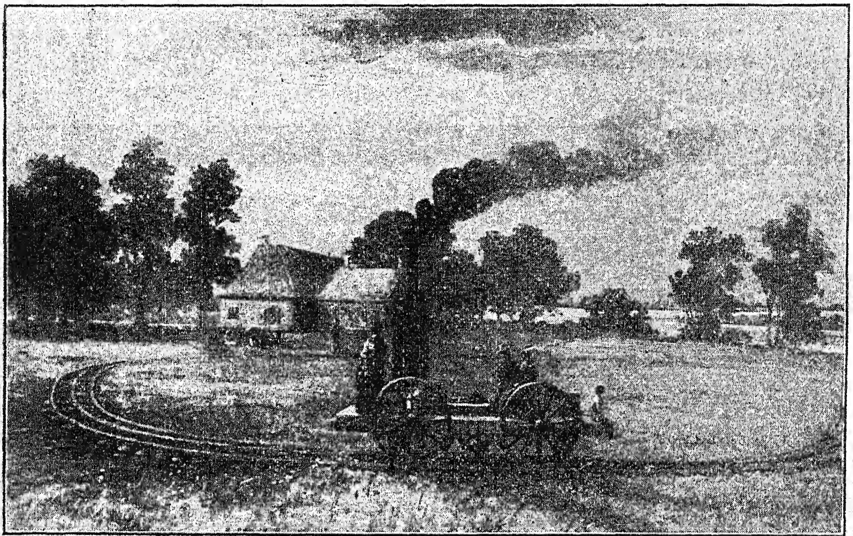
Development of the American Locomotive

Oliver Evans and Colonel John Stevens had proposed steam railways for the United States before the Stockton and Darlington experiments were made. Evans, as the chapter on the steam-engine recounts, was the inventor of the high-pressure steam-engine, and the builder of the first steam automobile, a vehicle which travelled not only on land but also in water. Again and again Evans advocated steam locomotion, first on turnpikes, then on rails after they were invented. Stevens was more concrete in his ideas, and more energetic. He applied for and received from the State of New Jersey, in 1815, the first American railway charter, although as early as 1810 he had been preaching the gospel of the steam railway.

While Stephenson was still experimenting with steam on the Stockton and Darlington, Stevens built a rack-rail engine that propelled itself by a cog-wheel engaging a rack bolted to the ties. Constructed in 1825 to run between Philadelphia and Columbia, the engine had a vertical boiler—a multitubular boiler. Hence Stevens actually anticipated Stephenson in the use of fire-tubes, although both fire-tube and water-tube boilers were patented before Stevens's or Stephenson's day. The wheels

of Stevens's engine were kept on the track not by the usual flanges but by small side horizontal friction-wheels.

America was no more favorably inclined to such experiments than was England. The idea of a boiler and engine mounted on wheels as a substitute for horses was received with doubt and derision. When, in 1830, the Baltimore and Ohio



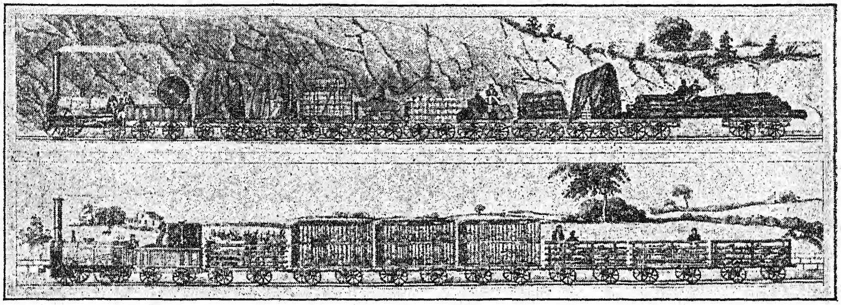
Courtesy of the Stevens Institute of Technology.

THE FIRST STEAM LOCOMOTIVE IN AMERICA.

On this private track, built in Hoboken, Colonel John Stevens in 1826 (he was then seventy-six years old) operated an experimental locomotive with a multitubular boiler of his own invention.

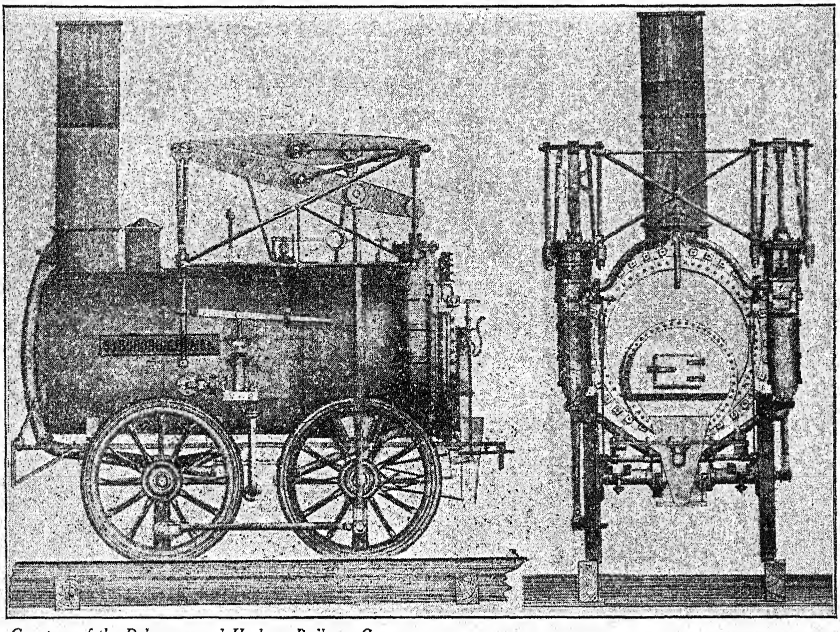
Railroad was opened with horse and rail cars, Daniel Webster expressed grave doubts as to the ultimate success of the railroad, saying among other things that the frost on the rails would prevent a train from moving, or if it did move, from being stopped, which shows that whatever may have been Webster's ability as a lawyer, his knowledge of mechanics was not even rudimentary.

In view of the work that had been done in England it was natural that the early American promoters of railroads should look to that country for their motive power. The Delaware and Hudson Canal Company sent Horatio Allen to England to buy



Courtesy of the South Kensington Museum.

EARLY FREIGHT-TRAINS OF THE LIVERPOOL AND MANCHESTER RAILWAY.



Courtesy of the Delaware and Hudson Railway Company.

THE STOURBRIDGE LION.

This was the first locomotive that ran in commercial service in the United States. The locomotive was tested in 1829 by Horatio Allen, and proved to be too heavy for the light American tracks of that period. It was imported by the Delaware and Hudson Company from England.

iron rails and two locomotives. The "America," built to Allen's order by George Stephenson, was practically a duplicate of the famous "Rocket," but the four wheels were coupled to give better adhesion and a greater tractive power—the first stage in the development of the many-coupled American locomotive.

There is no known record of the "America's" performance in this country. The other locomotive ordered by Allen, the "Stourbridge Lion," built at Stourbridge, England, was the first locomotive that ran in commercial service in America. In August, 1829, with Horatio Allen at the throttle, the engine made its trial trip. It had two vertical cylinders operating two overhead walking beams, from which connecting-rods ran to the driving-wheels, and must have appeared like a marine engine on wheels.

Allen tested the "Stourbridge Lion" with some trepidation. He had specified a locomotive weighing three tons; he received one weighing seven. On August 9, 1829, the engine was placed on the tracks at Honesdale. Allen knew that the track was too light, but he determined to take the risk. Nobody accepted his invitation to ride with him. Bidding good-by to the onlookers he dashed off and, probably to his own surprise, quickly found himself out of sight. In 1884 Mr. Allen wrote the following humorous account of the first American trial of the "Stourbridge Lion":

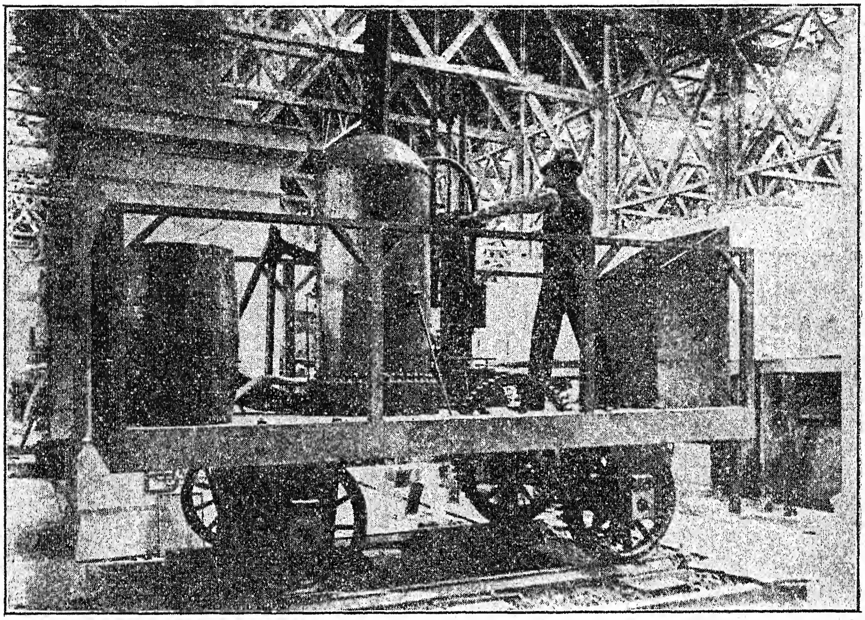
"When the time came, and the steam was of the right pressure, and all was ready, I took my position on the platform of the locomotive alone, and with my hand on the throttle-valve handle, said: 'If there is any danger in this ride it is not necessary that the life and limbs of more than one be subjected to danger.'

"The locomotive, having no train behind it, answered at once to the movement of the hand; . . . soon the straight line was run over, the curve was reached and passed before there was time to think as to its not being passed safely, and soon I was out of sight in the three miles ride alone in the woods of Pennsylvania. I had never run a locomotive nor any other engine before; I have never run one since."

The engine proved satisfactory enough on the coal docks of the Delaware and Hudson Company, but it was too heavy for

the regular tracks. It was withdrawn from service after a short time.

The truth was that the English locomotives were not adapted to run on the flimsy American tracks; moreover they burned coke and not wood. Yet these poorly laid, light rails proved



Courtesy of the Baltimore and Ohio Railroad.

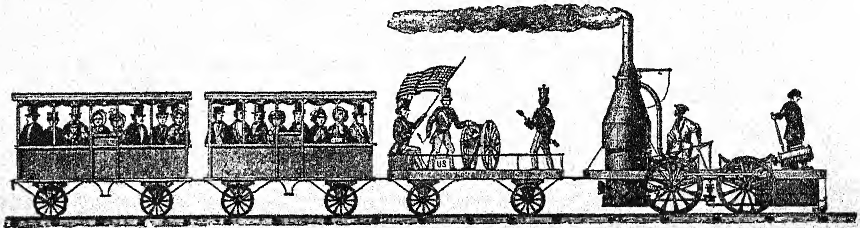
MODEL OF PETER COOPER'S "TOM THUMB."

Peter Cooper was one of the pioneers of the American railroad. His "Tom Thumb" locomotive had a short career on the Baltimore and Ohio Railroad in 1830. All the locomotives of the early thirties were but little larger than a modern fire-engine. They were too light to haul heavy loads.

to be the incentive needed for America to design and build her own locomotives and introduce characteristically American improvements. Peter Cooper, Long and Norris, and Rogers were especially prominent among those who struck out along new lines.

The earliest American locomotive was Peter Cooper's "Tom Thumb," which had a brief existence on the Baltimore and Ohio Railroad in 1830—so brief, in fact, that it deserves no extended description. The "Best Friend," built at the West

Point Foundry in 1830 for the South Carolina Railroad Company, is really the patriarch of American locomotives. The "Best Friend" was what railway engineers call "four-coupled"; that is to say the four wheels were connected by outside coupling-rods; it was also "inside-connected," meaning that the cylinders were inside the frames and coupled to two cranks on the driving-axle. The cylinders were six inches by sixteen-inch



Courtesy of the Southern Railway Company.

THE "BEST FRIEND."

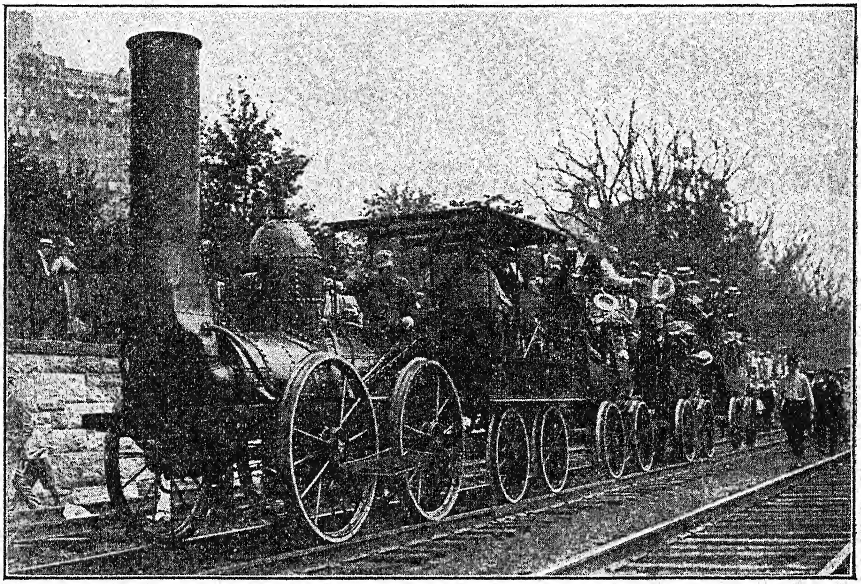
The "Best Friend" was built at the West Point Foundry shops in New York City for the South Carolina Railroad, arrived by the ship *Niagara*, October 27, and after experimental trials, in November and December, 1830, made the first excursion trip here pictured, on Saturday, January 15, 1831. The "Best Friend" was the first locomotive built in the United States for actual service.

stroke; the driving-wheels were four feet nine inches, and the weight was four and one-half tons.

The West Point Foundry, New York, will always possess strong historical interest, since here were built the first practical American locomotives. Following the "Best Friend," this shop turned out the "West Point," which had a horizontal boiler, and conformed more to the type which has survived. It hauled 117 passengers in four cars, and between the locomotive and the cars was a "barrier car."

This "barrier car" was an interesting innovation, invented solely and simply to ease the anxiety of the passenger. It was a car loaded with bales of cotton, which, says Angus Sinclair in his *Development of the American Locomotive*, was widely advertised as a good protection to the passengers "when the locomotive exploded." The boiler of the "Best Friend" had exploded, and this little weakness seems to have been generally accepted as unavoidable.

Following the "West Point" came the most famous of all pioneer American locomotives, the "De Witt Clinton." Built at West Point in 1831 for the Mohawk and Hudson Railroad it made its first run on August 9 of that year from Albany to Schenectady, and with a load of three coaches it attained a



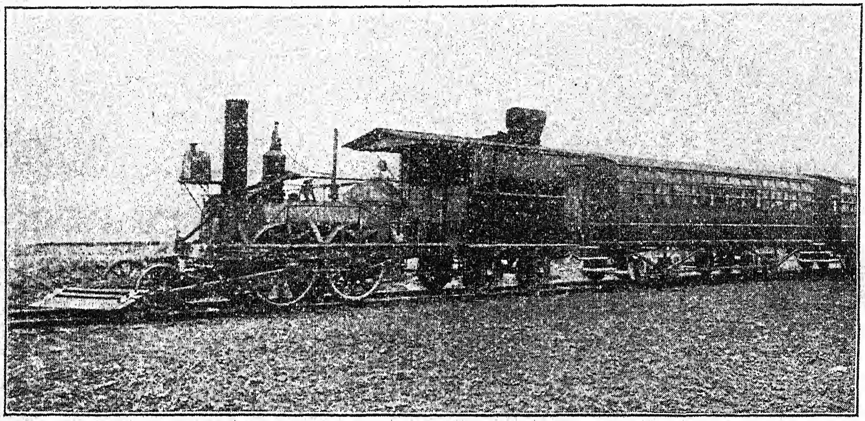
Courtesy of the New York Central Lines.

THE "DE WITT CLINTON."

The "De Witt Clinton" was the first American passenger-locomotive. It hauled its first train on August 9, 1831, over the Mohawk and Hudson Railroad, now a part of the New York Central system. The trip between Albany and Schenectady, a distance of seventeen miles, was made in one hour and forty-five minutes. The maximum speed attained was thirty miles an hour. Upon arrival at Schenectady the train was greeted by bands and the roar of cannon. The "De Witt Clinton" made the return trip from Schenectady to Albany with five coaches in thirty-eight minutes. After fourteen years of service the "De Witt Clinton" was then stored at Karner, near West Albany, from which place it was moved in June, 1920, and placed on exhibition in the Grand Central Terminal. The old locomotive is here shown on the tracks of the present New York Central Railroad.

speed of fifteen miles an hour. Alone, the "De Witt Clinton" made a speed of forty miles an hour. The cylinders were five and one-half inches in diameter by sixteen inches stroke, direct-connected to coupled wheels four feet six inches in diameter. The boiler contained thirty copper tubes, and the weight of the engine was six tons.

A full-size model of this early train was shown at the Chicago Exposition of 1893; and in 1921 it was run under its own steam on various stretches of track throughout the country, before being exhibited in Chicago. Millions of people looked with wonderment at this curious example of how our forefathers attempted to solve the problem of transportation. The influence



Courtesy of the Pennsylvania Railroad

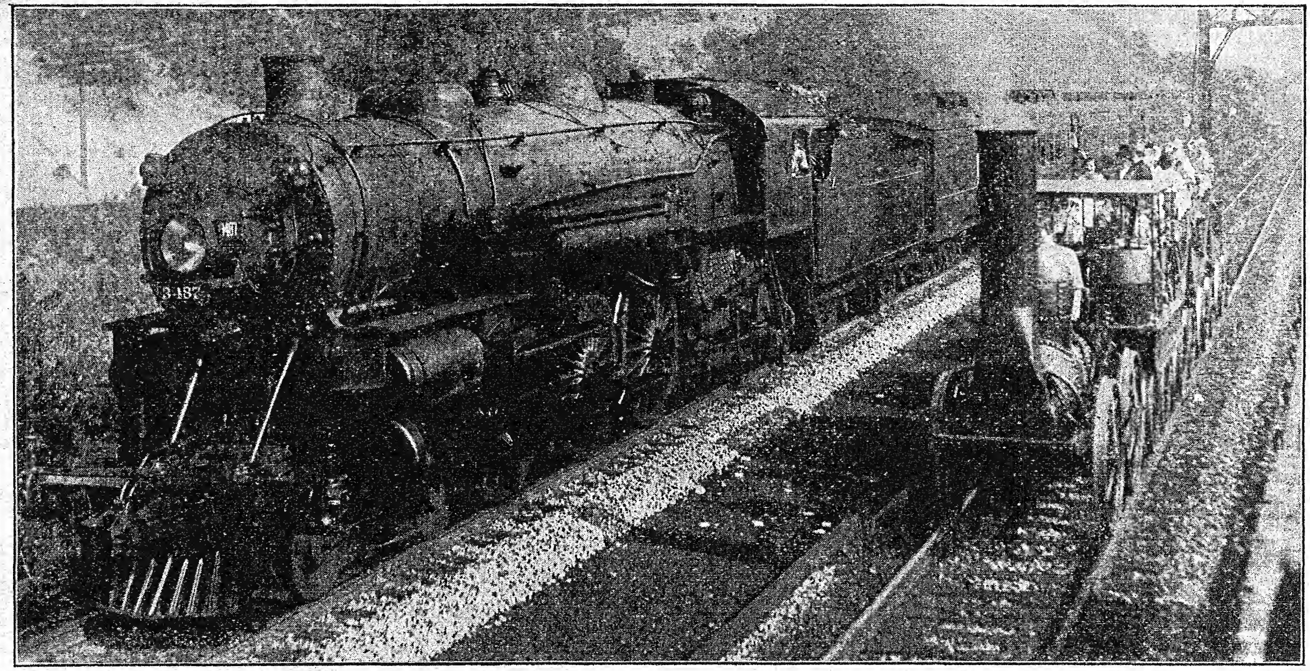
THE "JOHN BULL."

To meet the demand for greater hauling power, Robert L. Stevens imported the "John Bull" for the Camden and Amboy line, now part of the Pennsylvania system. Finding the English locomotive too rigid for the sharp curves, Isaac Dripps, of the Camden and Amboy, removed the coupling-rods of the wheels, gave one and one-half inches play sidewise to the leading axle, and attached in front a two-wheeled pilot or cowcatcher, which relieved the leading driving-wheels of some of the superimposed weight—characteristics of American locomotives to this day.

of the early stage-coach is seen in the construction of the passenger-cars—a subject to which reference will be made later on.

Riding behind the "De Witt Clinton" or any of its contemporaries was not an unmixed blessing. William H. Brown, one of the passengers hauled by the "De Witt Clinton" when the Mohawk and Hudson was opened on August 9, 1831, gives this description of his experiences:

"John T. Clark, as the first passenger-railroad conductor in the North, stepping from platform to platform outside the cars, collected the tickets which had been sold at hotels and other places through the city. When he finished his tour he mounted upon the tender attached to the engine, and sitting upon the



Courtesy of the New York Central Lines.

THE "DE WITT CLINTON" AND A PACIFIC LOCOMOTIVE.

The combined weight of the "De Witt Clinton" and its tender was 12,098 pounds. This was less than the weight of a pair of driving-wheels of a Pacific locomotive, which weigh 13,000 pounds. The standard Pacific-type locomotive shown weighs 276,000 pounds, which is about eleven times the weight of the entire "De Witt Clinton" train. The tender of a Pacific locomotive when loaded weighs 158,000 pounds, so that the total weight of engine and tender is 434,000 pounds, a little more than seventeen and one-half times the total weight of the "De Witt Clinton" train. The "De Witt Clinton" locomotive is 12 feet long; the length of the tender is 10 feet 11 inches. Each coach is 14 feet long, so that the train is 65 feet 9 inches long. A Pacific-type locomotive without its tender is 78 feet 2⅜ inches long, or 12 feet 5⅜ inches more than the total length of the "De Witt Clinton" train.

little buggy seat, gave the signal with a tin horn, and the train started on its way. But how shall we describe that start? There came a sudden jerk that bounded the sitters from their places, to the great detriment of their high-top, fashionable beavers from the close proximity to the roofs of the cars. This first jerk being over, the engine proceeded on its way with considerable velocity, when compared with stage-coaches, until it arrived at a water station, when it suddenly brought up with jerk number two to the further amusement of some of the excursionists. Mr. Clark retained the elevated seat, thanking his stars for its close proximity to the tall smoke-pipe of the machine in allowing the smoke and sparks to pass over his head."

These locomotives of the early thirties were little larger than modern fire-engines. The weight of the first Baltimore and Ohio regular locomotives was only three and one-half tons. The companies soon found that locomotives weighing less than ten tons were too weak for hauling heavy loads, and that small cars had too much dead weight relatively to the paying load.

There came a demand for greater hauling power, and to meet it Robert L. Stevens imported the "John Bull" for the Camden and Amboy line. The cylinders were nine inches by twenty inches, and the weight was ten tons—a big advance in power and size. Isaac Dripps of the Camden and Amboy road, finding the English locomotive too rigid for the sharp curves of American roads, removed the coupling-rods of the wheels, gave one and one-half inches side play to the leading axle, and attached in front a two-wheeled pilot or cowcatcher, which relieved the leading driving-wheels of some of the superimposed weight; characteristics that distinguish the American locomotive of to-day. Indeed, the "John Bull," as improved by Dripps, was not only the first to have a cowcatcher, but it also introduced the bell and the headlight.

Some extraordinary designs were produced during all this pioneer work—locomotives of such fantastic shape that they were given the name their shape suggested. One does not usually associate a locomotive with a grasshopper, and yet the Baltimore and Ohio Railroad in the early thirties used several "Grasshoppers," whose advantage over the insect lay principally in the matter of size and noise. A vertical boiler, two vertical

ten-inch cylinders, a pair of rocker-shafts, a pair of connecting-rods, some gear-wheels, outside cranks and coupling-rods served to transmit the power to the wheels.

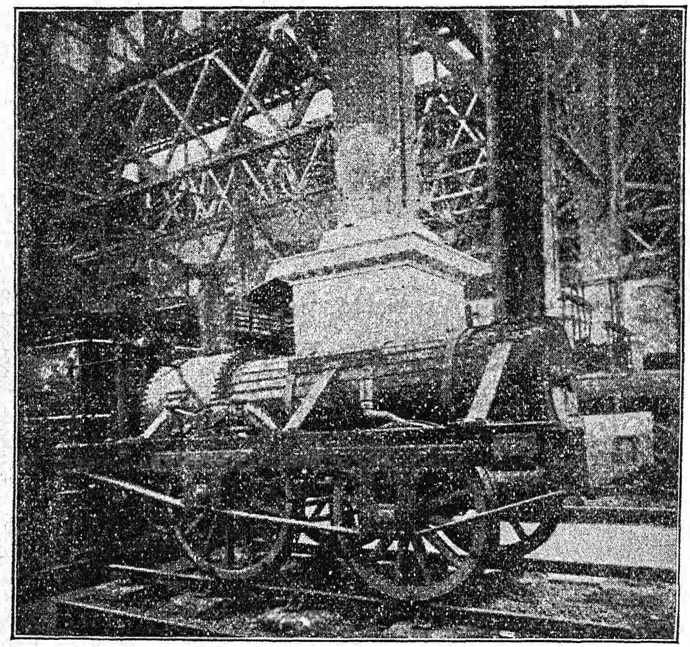
It is important that the steam in a locomotive be properly controlled in the cylinders, and the year 1832 is notable for the invention of the "link-motion" by William T. James of New York. It was one of the simplest, most efficient, and most enduring of inventions. Hitherto, valve-gears were crude, complicated, and inefficient. James connected the eccentric-rod ends by a curved and slotted link carrying a sliding block, to which was fastened the valve-stem. By means of a hand-lever the engineer lifted or depressed the link, thereby throwing the gear into forward or reverse operation.

The Rise of Matthew Baldwin

Some mechanics drifted into engine-building in queer ways. There was Matthew Baldwin, for example, founder of the famous Baldwin Locomotive Works, a jeweller by trade, who was engaged in the manufacture of bookbinder's tools and calico-printing machinery in 1825. Needing an engine that would occupy the least possible space in his shop, he proceeded to design it himself. This engine attracted so much attention that he received orders for duplicates. Thus he was launched as an engine-builder, a career of which he probably never dreamed in the days when he was a jeweller. Franklin Peale, proprietor of the Philadelphia Museum, asked Baldwin to construct a working miniature locomotive for exhibition. Baldwin had never seen a locomotive. With the aid of inadequate sketches of the "Rocket," which had won the Liverpool and Manchester contest, he succeeded in producing a little engine which hauled two cars seating four passengers. Peale did a thriving business with this little train.

Thus was Baldwin fairly started as a locomotive-builder. In 1832 he was asked to build a locomotive for the Philadelphia, Germantown and Norristown Railroad. He studied the imported Camden and Amboy locomotives, and constructed the "Old Ironsides," which marked an advance on the "John Bull." The cylinders were nine and one-half inches by eighteen, and the boiler contained thirty copper tubes. American builders

soon abandoned copper for the tubes, though the English retained the practice. The engine weighed eight tons, and could haul thirty tons on a level road. "Old Ironsides" was the first steam-engine to be built by a firm destined to become known all over the world for its construction of locomotives.



Courtesy of the Baltimore and Ohio Railroad.

"OLD IRONSIDES."

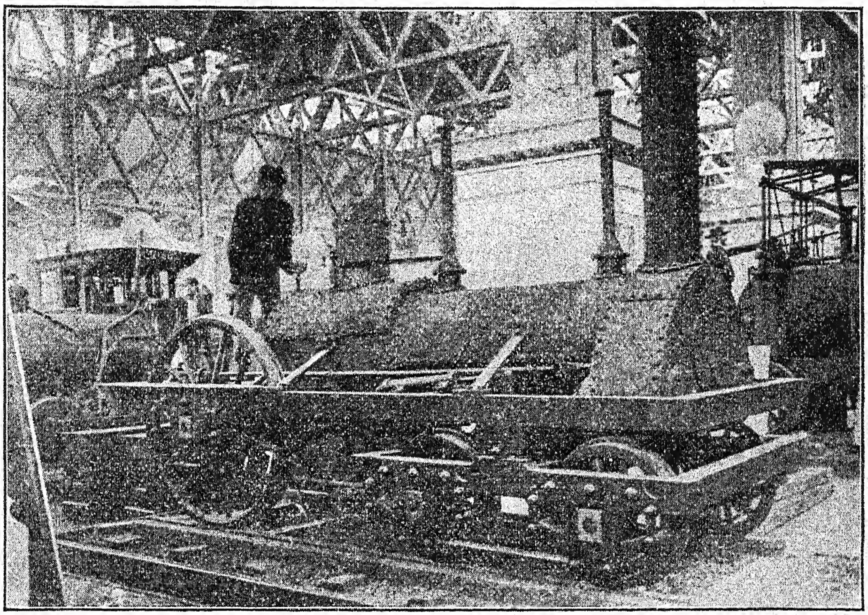
Matthew Baldwin studied the locomotives imported from England in the early thirties and proceeded to construct the "Old Ironsides," of which this is a reproduction made by the Baltimore and Ohio Railroad. The engine weighed eight tons, and could haul thirty tons on a level road.

The Swivelling Truck and the Equalizing-Lever

Pioneer railroad-builders in England were justified in spending more money in constructing their roads than we could afford to spend in America. That country was settled; passengers and freight were abundant; the new roads were certain to pay good dividends from the very start. So the roads were built straight and level, with masonry or iron bridges. In the United States the new roads were built largely through sparsely settled coun-

try, where freight and passengers were comparatively scarce. In England, the country developed the railroads; in the United States the railroads developed the country.

Our early roads had so many sharp curves and heavy grades that, eventually, the American locomotive was designed to meet them. It had to be flexible to run around sharp curves and



Courtesy of the Baltimore and Ohio Railroad.

MODEL OF JOHN B. JERVIS'S "EXPERIMENT."

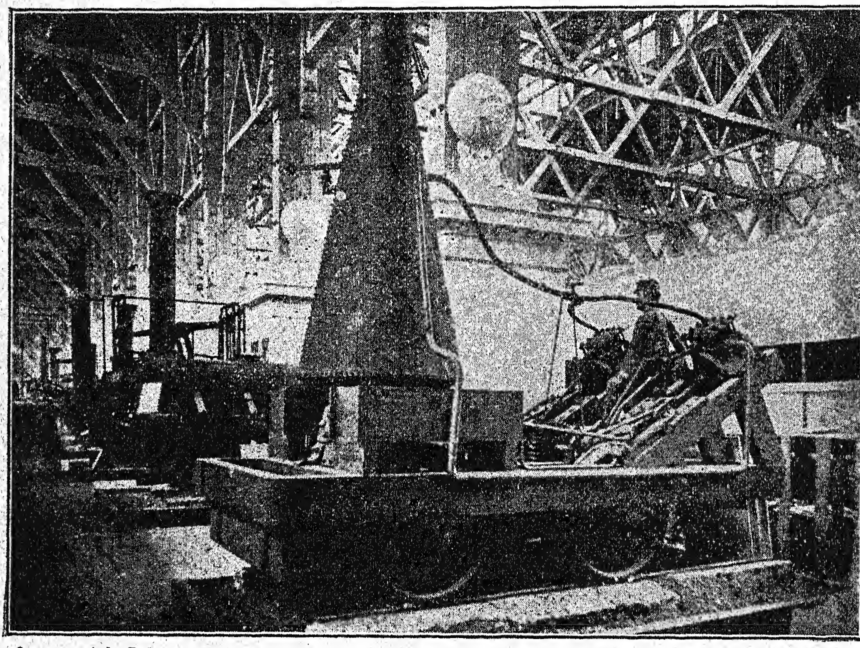
The "Experiment" was built in 1832 by the Baltimore and Ohio Railroad. This was the first locomotive that had a swivelling truck capable of turning horizontally about a centre-pin, an invention made necessary by the sharp curves and rough tracks of the time. The cylinders were coupled to single driving-wheels, and the weight was over seven and one-half tons.

over rough track; it had to be powerful to surmount heavy grades; it had to be heavy, with many driving-wheels, to be able to haul heavy loads. For this reason our trains have grown to be far heavier and our locomotives more powerful than those of the older countries.

The credit for designing the first locomotive with a swivelling truck, capable of turning horizontally about a centre-pin, goes to John B. Jervis, chief engineer of the Mohawk and Hudson

Railroad, who in 1832 placed the "Experiment" in service. The cylinders were coupled to single driving-wheels, and the weight was over seven and one-half tons.

It became apparent that if the locomotive was not to cause the track to sink the weight must be distributed over the rails.



Courtesy of the Baltimore and Ohio Railroad.

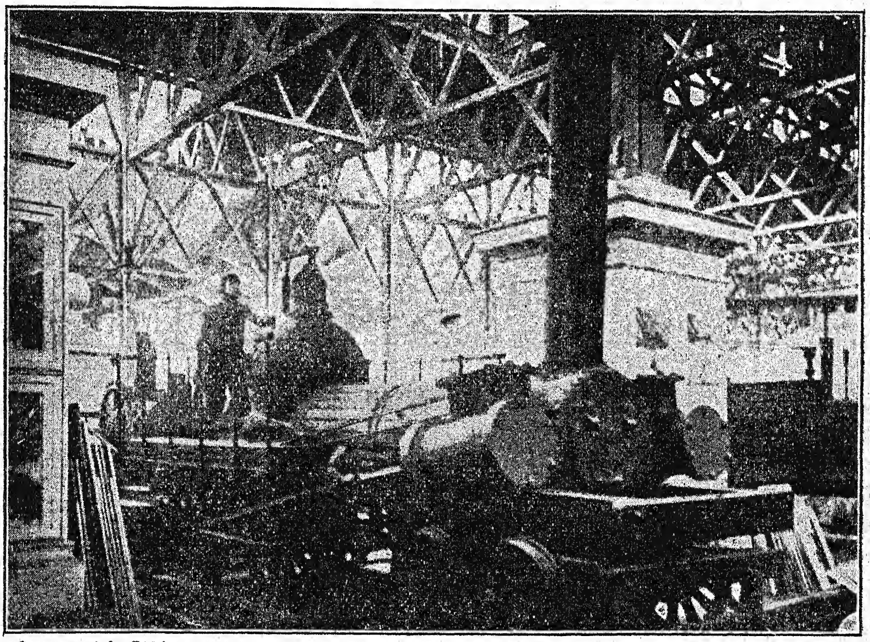
WILLIAM JAMES'S LOCOMOTIVE.

The steam in a locomotive's cylinders must be properly controlled. The locomotive invented by William James, of New York (of which this is a reproduction made by the Baltimore and Ohio Railroad), is historically important. It incorporated for the first time the modern "link-motion," one of the simplest and most enduring of inventions.

The principle is much the same as that applied in the snow-shoe or the ski. A man on snow-shoes can stand on the surface of loose snow because his weight is distributed over several square feet; in boots he would sink in. Horatio Allen was the first to suggest this principle in locomotives, although it remained for John Jervis to carry it out. Jervis ordered from H. R. Campbell for the Germantown railroad, the first eight-wheel locomotive—a type that has prevailed for over half a century. It was called the "Experiment." Weights and power

were going up. This engine had cylinders fourteen by sixteen inches, and it weighed twelve tons.

The roughness of the track led to another valuable improvement: the equalizing-lever. It was a strong flat bar, pivoted at its centre to the locomotive frame, with its ends resting upon



Courtesy of the Baltimore and Ohio Railroad.

THE "HERCULES" OF HARRISON.

Rough tracks inspired Joseph Harrison to invent the equalizing-lever—a flat bar pivoted at its centre through a spring to the frame, with its ends resting upon the journal-boxes of the adjoining driving-wheels. The lever distributed the shock or "hammer-blow" due to bumps or hollows of the track. The locomotive in which Harrison incorporated this invention in 1837 was the "Hercules," of which this is a reproduction made by the Baltimore and Ohio Railroad.

the journal-boxes of the adjoining driving-wheels. The new device distributed the shock or "hammer-blow," due to passing over bumps or hollows of the track, evenly over the two wheels. The "Hercules" of 1837 was the first to embody the equalizing-lever, and to Joseph Harrison goes the credit for this notable engine, a full-size model of which is in the Field Museum, Chicago.

Typical American-Type Locomotive of 1845

The famous Rogers Locomotive Works of Paterson, N. J., was responsible for many improvements, notably the placing of a balance weight at the rim of the driving-wheel to counteract the back-and-forth surging and hammering effects of the piston, connecting-rods, etc. This was done in the "Sandusky." Rogers also placed the cylinders outside the frames, used bar iron in opposition to the English plate-frames, and by combining these features with the equalizing-lever and a forward truck, he produced the typical American outside-connected, eight-wheel engine, which remained the standard passenger-engine for fifty years. This locomotive, with cylinders eleven and one-half inches by eighteen, and five-foot drivers, was built in 1845 for the New Haven and Hartford road.

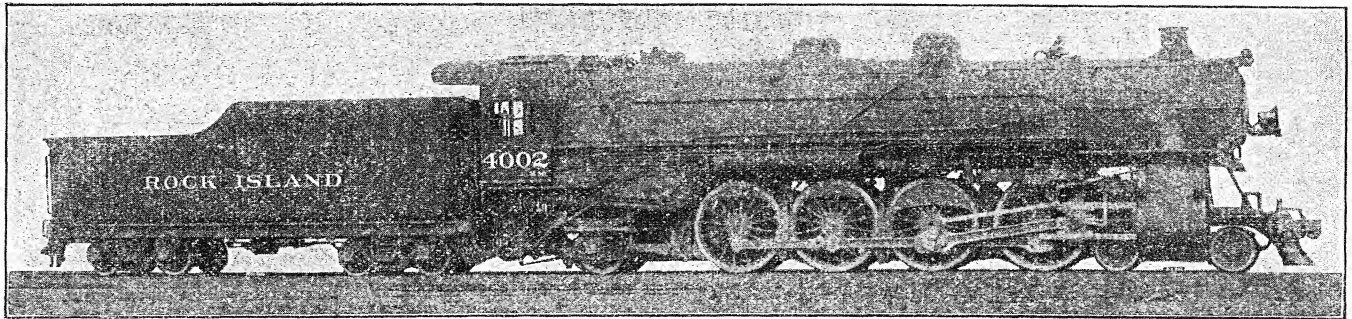
The increased length and weight of American passenger-trains demanded powerful engines. They were an absolute necessity. Hence in locomotives we find first the four-coupled, then the six-coupled, and finally in the latest Rock Island locomotive, the eight-coupled.

The Largest Express Locomotive

Bear in mind the modest dimensions of the early locomotives above described, and compare them with the following figures for the Rock Island Locomotive—the most powerful passenger locomotive in the world in 1921:

Length over all	90 feet
Weight	270 tons
Diameter of boiler	80 inches
Boiler pressure per square inch	200 pounds
Diameter of cylinders	28 inches
Stroke of cylinders	28 inches
Draw-bar pull	25 tons

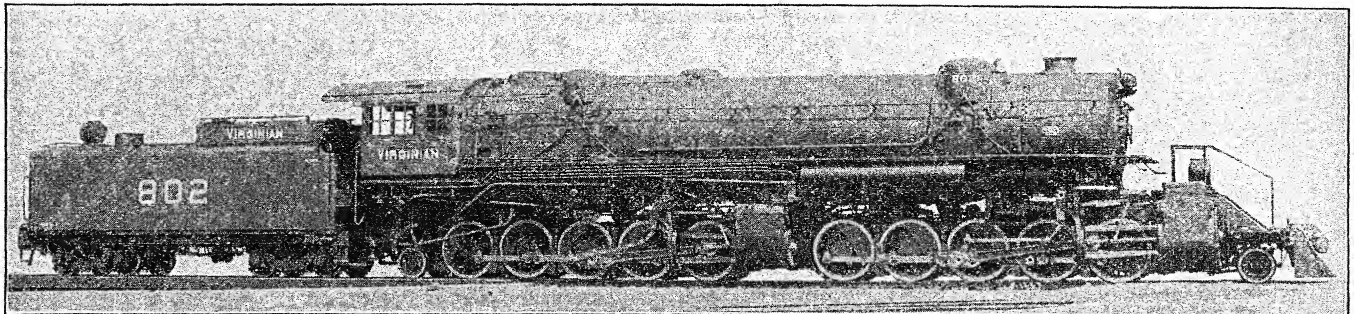
This engine has hauled sixteen Pullman cars, weighing twelve hundred tons, at a speed on level track of slightly more than sixty miles an hour.



Courtesy of the American Locomotive Company.

THE MOST POWERFUL PASSENGER LOCOMOTIVE (ROCK ISLAND LINE).

Length over all, 90 feet; weight, 270 tons; diameter of boiler, 80 inches; boiler pressure per square inch, 200 pounds; diameter of cylinders, 28 inches; stroke of cylinders, 28 inches.



Courtesy of the American Locomotive Company.

THE MOST POWERFUL FREIGHT LOCOMOTIVE, THE "VIRGINIAN" (MALLET COMPOUND).

Length over all, 107 feet; weight, 450 tons; diameter of boiler, 103 inches; boiler pressure per square inch, 215 pounds; diameter of cylinders: high pressure, 30 inches; low pressure, 48 inches; stroke of cylinders, 32 inches; total heating surface, 10,725 square feet.

The American Freight Locomotive

Freight-trains, also increasing their weight, called for more power, and this in turn demanded larger boilers and cylinders; these again required additional weight on the drivers to prevent their slipping on the rails. The problem was met by adding yet another pair of wheels and coupling all six together. The first of this type known as the "Mogul" was built in 1863 at the Rogers Works. A two-wheel pony truck took the place of the four-wheel truck. The cylinders were large, seventeen inches by twenty-two, and the weight went up to thirty-five tons.

The next step in weight and power was taken by the Baldwin Locomotive Works. They added another pair of drivers, and in 1866 produced the first "Consolidation"—a type which, like the "Mogul," was to endure to our day. The cylinders were twenty inches by twenty-four, and the weight went up to forty-five tons, about one-tenth the weight of the largest locomotive of to-day.

Hitherto the main efforts of locomotive-builders had been directed toward an increase of power; if engines pulled the load, that was sufficient. But in the latter half of the nineteenth century they aimed at an economical machine that would have the maximum of hauling power with the least possible consumption of fuel. The builders of steamship engines had already found that a given amount of steam would do more work if it were first used in a high-pressure cylinder, and then exhausted to a larger, low-pressure cylinder. The locomotive-builders began to use this method. In the period 1890 to 1910 thousands of compound locomotives were built, some with one high-pressure cylinder and one low-pressure, some with two high and one low, and others with two high and two low. Some economy resulted, but the gain was not so marked as in the steamship engines, where first compound, then triple-expansion, and finally quadruple-expansion engines, in which the steam passed through four successive cylinders, proved very economical.

In general, compounding failed to show a sufficient saving in steam, and therefore in coal, to justify its general adoption. A better way has been found in superheating. In this method,

the steam in its passage from the boiler to the cylinders, is led through tubes around which pass the hot gases from the fire-box. The steam is thereby dried, and its temperature is raised several hundred degrees. Heat is power, and the heat drawn from the hot gases represents an equivalent gain of power in the cylinders. Now, this heat is a clear gain; but without the superheater it would have passed out through the smoke-stack and been lost.

Locomotive engineers estimate that the use of superheaters represents a saving of about twenty-five per cent in coal. In other words, if a simple locomotive does a certain amount of work for every ton of coal burned, a superheater locomotive will do the same work on about three-quarters of a ton.

It would take more than a volume to trace in detail the growth of the freight locomotive from the fifties to the present day. We have seen how its essential features came, one by one, to be incorporated; from then on growth was in the direction of size, weight, and power. The true measure of a locomotive's power is the size of its boiler, and American engineers have never lost sight of this fact; in fact our locomotives have always carried a much larger boiler than those of any other country. Moreover, we have consistently used higher steam pressures.

It should be remembered that a sufficient number of wheels must be coupled together and a sufficient part of the weight of the freight locomotive be carried by them, to prevent the power of the cylinders from slipping the wheels. Hence, as boilers and cylinders grew in size, more pairs of wheels had to be coupled together. In the freight-engine, there was first the "Mogul" (six-coupled); then the "Consolidation" (eight-coupled), followed by the "Decapods" (ten-coupled). This was the limit.

A way of gaining further adhesion was found in using the invention of the Frenchman, Mallet, who provided two separate trucks below the boiler, each of which carried a pair of cylinders coupled to a set of drivers. This opened up great possibilities of power. Longer boilers could be used, more drivers could be utilized, and the adhesion and tractive power increased.

The accompanying illustration of the "Virginian" shows the

most powerful freight steam locomotive in the world. Its proportions are enormous:

Length over all	107 feet
Weight	450 tons
Diameter of boiler	103 inches
Boiler pressure per square inch	215 pounds
Diameter of cylinders:	
High pressure	30 inches
Low pressure	48 inches
Stroke of cylinders	32 inches
Total heating surface	10,725 square feet

This engine during a test hauled a coal train weighing 17,600 tons up a long two-tenths of one per cent grade. The American Locomotive Company built this mastodon.

The American Passenger-Car

The first passenger-car that ran on the Baltimore and Ohio was described by an eye-witness as "a little clapboarded cabin on wheels, for all the world like one of those North Carolina mountain huts, with the driver perched on top of the front portico—driver, because the motive power then was one horse in a treadmill-box."

A glance at the "De Witt Clinton" steam train shows that the more comfortable early passenger-car was the body of a stage-coach mounted upon four iron wheels. Some of the passengers sat upon the roof, stage-coach fashion, where they were not only exposed to wind and rain but also to the smoke and hot sparks of the wood fuel with which the locomotive was fired. Later, to provide the passengers with better shelter and comfort, closed box-like cars were introduced; but these brought discomforts of their own.

That a railway journey in the early days of the steam locomotive was something to be dreaded may be gathered from this extract from the diary of pessimistic Samuel Breck of Boston:

"*July* 22, 1835. This morning at nine o'clock I took passage on a railroad-car (from Boston) for Providence. Five or six other cars were attached to the locomotive, and uglier boxes I do not wish to travel in. They were made to stow away some

thirty human beings, who sit cheek by jowl as best they can. Two poor fellows who were not much in the habit of making their toilet, squeezed me into a corner, while the hot sun drew

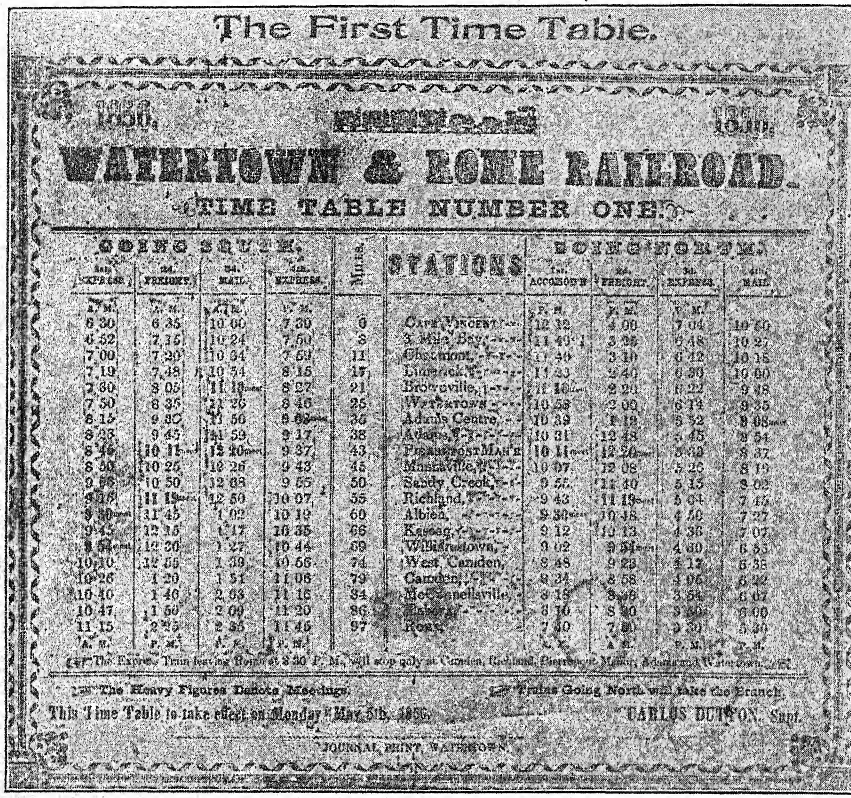
Courtesy of the New York Central Lines.

POSTER USED IN 1854 AND 1855 TO ADVERTISE THE NEW YORK CENTRAL RAILROAD AND ITS CONNECTIONS.

from their garments a villainous compound of smells made up of salt fish, tar, and molasses. By and by just twelve—only twelve—bouncing factory girls were introduced, who were going on a party of pleasure to Newport. 'Make room for the ladies!' bawled out the superintendent. 'Come, gentlemen, jump on

the top; plenty of room there!' 'I'm afraid of the bridge knocking my brains out,' said a passenger. Some made one excuse, and some made another. For my part I flatly told him that since I had belonged to the corps of Silver Grays I had lost my gallantry and did not intend to move. The whole twelve, how-

14,637



The First Time Table.

1856. 1856.

WATERTOWN & ROME RAILROAD.

TIME TABLE NUMBER ONE.

Going South: Express	Going South: Freight	Going South: Mail	Going South: Express	Miles	STATIONS	Going North: Accomod'n	Going North: Freight	Going North: Express	Going North: Mail
A. M.	P. M.	A. M.	P. M.			P. M.	P. M.	P. M.	
6 30	6 35	10 00	7 30	0	Cape Vincent	12 12	4 00	7 04	10 50
6 52	7 15	10 24	7 50	8	3 Mile Bay	11 49	3 35	6 48	10 27
7 00	7 20	10 34	7 59	11	Chaumont	11 40	3 10	6 42	10 18
7 19	7 48	10 54	8 15	17	Limerick	11 23	2 40	6 30	10 00
7 30	8 05	11 10	8 27	21	Brownville	11 10	2 20	6 22	9 48
7 50	8 35	11 26	8 46	25	Watertown	10 53	2 00	6 14	9 35
8 15	9 30	11 50	9 02	36	Adams Centre	10 39	1 19	5 52	9 08
8 23	9 45	11 59	9 17	38	Adams	10 31	12 48	5 45	8 54
8 40	10 11	12 20	9 37	43	Pierrepont Man'r	10 11	12 20	5 32	8 37
8 50	10 25	12 26	9 43	45	Mannsville	10 07	12 08	5 26	8 19
9 06	10 50	12 38	9 55	50	Sandy Creek	9 55	11 40	5 15	8 02
9 16	11 15	12 50	10 07	55	Richland	9 43	11 19	5 04	7 45
9 30	11 45	1 02	10 19	60	Albion	9 30	10 48	4 50	7 27
9 45	12 15	1 17	10 35	66	Kasoag	9 12	10 13	4 36	7 07
9 54	12 30	1 27	10 44	69	Williamstown	9 02	9 54	4 30	6 55
10 10	12 55	1 39	10 56	74	West Camden	8 48	9 23	4 17	6 38
10 26	1 20	1 51	11 06	79	Camden	8 34	8 58	4 05	6 22
10 40	1 40	2 03	11 16	84	McConnellsville	8 18	8 36	3 54	6 07
10 47	1 50	2 09	11 20	86	[illegible]	8 10	8 30	3 50	6 00
11 15	2 25	2 35	11 46	97	Rome	7 40	7 30	3 30	5 30
A. M.	P. M.	P. M.	P. M.			A. M.	A. M.	P. M.	P. M.

The Express Train leaving Rome at 3 30 P. M. will stop only at Camden, Richland, Pierrepont Manor, Adams and Watertown.

The Heavy Figures Denote Meetings. Trains Going North will take the Branch.

This Time Table to take effect on Monday, May 5th, 1856. CARLOS DUTTON, Supt.

JOURNAL PRINT, WATERTOWN.

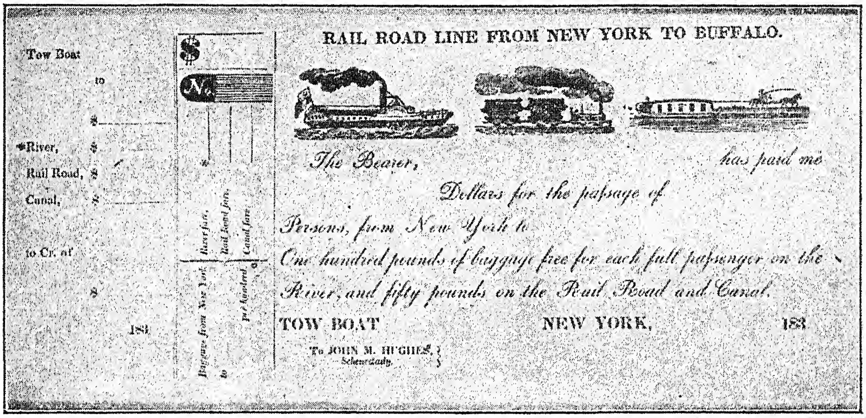
Courtesy of the New York Central Lines.

EARLY TIME-TABLE.

ever, were introduced and some made themselves at home, sucking lemons and eating green apples. . . . The rich and the poor, the educated and the ignorant, the polite and the vulgar, all herd together in this modern improvement in travelling . . . and all this for the sake of doing very uncomfortably in two days what would be done delightfully in eight or ten."

The cars in which Breck and his contemporaries had to ride were little more than wooden vans on wheels, slightly smaller

than the old-fashioned street-car. It was bad enough to be herded in these smelly vehicles and compelled to sit on hard wood, but as soon as the locomotive started passengers were choked with smoke and stung with road dust and flying sparks. At night, the few flickering candles were apt to fling their drip-


RAIL ROAD LINE FROM NEW YORK TO BUFFALO.

Tow Boat
to
$
River, $
Rail Road, $
Canal, $
to Cr. of
$
183

$
No.
River fare. Rail Road fare. Canal fare.
Baggage from New York to
per hundred.

The Bearer, has paid me
Dollars for the passage of
Persons, from New York to
One hundred pounds of baggage free for each full passenger on the River, and fifty pounds on the Rail Road and Canal.
TOW BOAT NEW YORK, 183
To JOHN M. HUGHES, Schenectady.

Courtesy of the New York Central Lines.

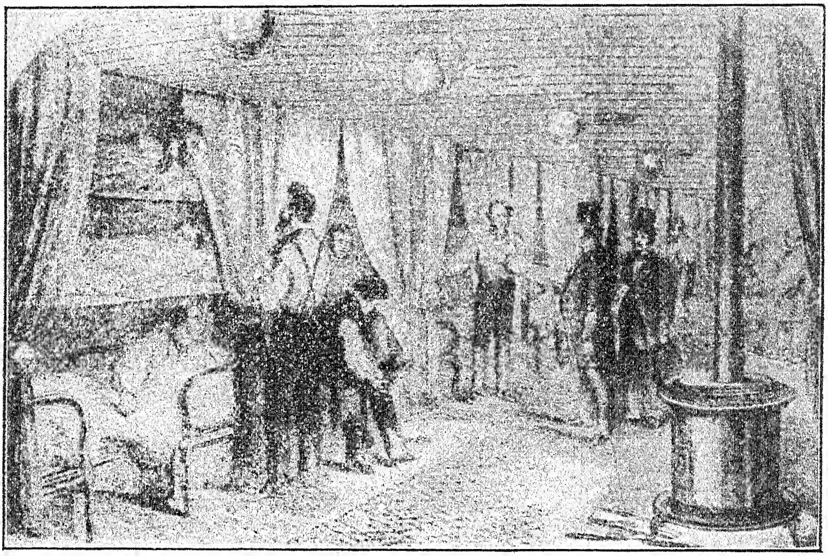
FORM OF TICKET ISSUED IN THE THIRTIES, GOOD ON RIVER STEAMBOAT, RAILROAD, AND CANAL-BOAT.

ping tallow on to the best of clothes. During the winter the cars were not ventilated, and the air was vitiated by a wood-burning stove that only made a pretense of furnishing heat.

Ross Winans introduced about 1832 a car mounted on two four-wheeled trucks. The sharp curves of the early roads brought about the use of the swivelling locomotive truck. Winans applied the idea to cars. His first car had seats inside and outside, arranged like those of stage-coaches. It was followed by a car which looked like three stage-coach bodies in one, divided into three compartments and entered by doors on the side of each compartment. The next improvement resulted in something more like the modern car—a vehicle with doors only at the ends, and with an aisle between seats extending through the car. Thanks to Winans the cars gradually grew in width, height, length, and weight. In Europe the separate-compartment idea prevailed, but in the United States the cars were open from end to end.

Thus was born the long, easy-riding typical American car, the most distinctive contribution of America to the convenience and safety of railroad travel.

Affecting the safety of passengers, a most important step was the introduction of the all-steel car. The wooden car was liable, in collision or derailment, to burst apart and splinter. In such accidents, the sharp broken timbers had caused fright-



Courtesy of the Pullman Company.

PULLMAN'S EARLY SLEEPING-CAR.

One of the oldest sleeping-cars, built on the style of the Erie Canal packet, with three tiers of bunks on one side of the car only. This preceded Pullman's No. 9 (his first modern car).

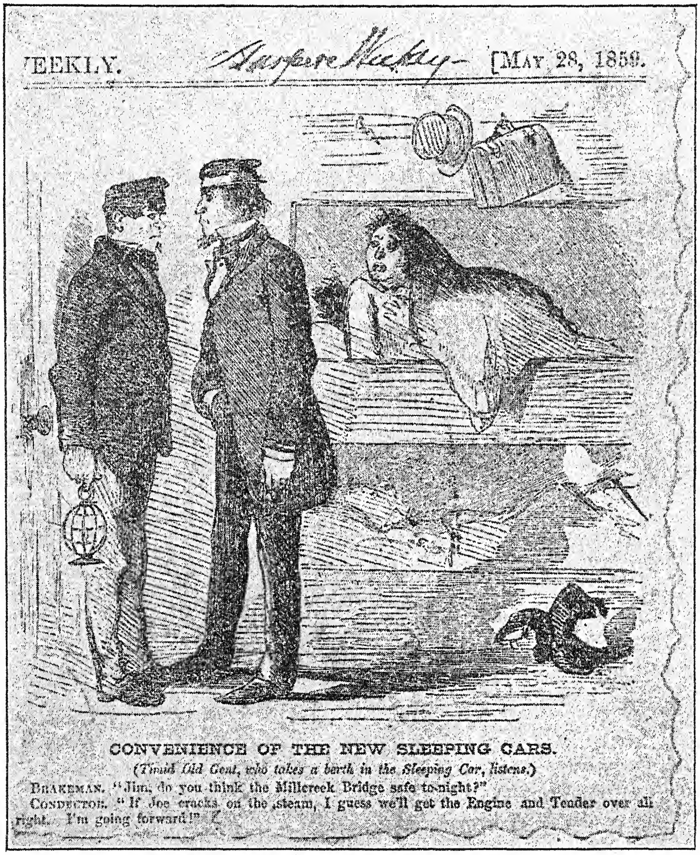
ful lacerations. Moreover, the whole car had burst into flame and the imprisoned passengers had been roasted to death. Now the steel car, with its greater strength, rarely telescopes, and though it may bend it will not break easily. It cannot catch fire. Passengers may be bruised, but even in severe collisions they are not likely to be killed.

Thus, from the small, uncomfortable, noisy boxes on wheels in which our forefathers travelled in the thirties, have developed the huge steel cars of to-day, eighty to ninety feet in length and weighing from eighty to ninety tons—cars in which

we may travel for days and nights, surrounded with many of the comforts of a city hotel.

How the Sleeping-Car Was Invented

The first trains were so slow and the distances to be covered so great that as early as 1836 the Cumberland Valley Railroad of Pennsylvania inaugurated a sleeping-car service between

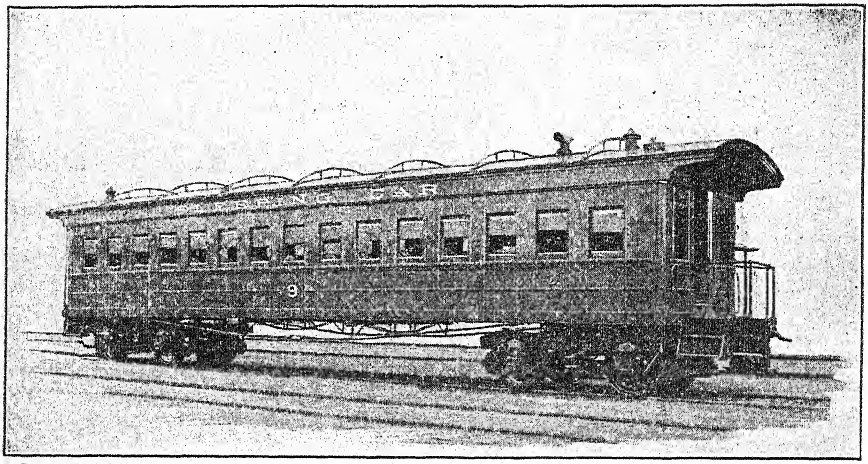


Courtesy of the Pullman Company.

INTERIOR OF A PULLMAN "BUNK" CAR.

Harper's Weekly of May 28, 1859, published this conception of sleeping-car comfort before George Pullman determined to make a night journey on a railroad somewhat more restful than it was in the days when he bumped over the tracks in the State of New York. These "bunk" cars were all that the travelling public could count upon for nearly a generation after the first railway was built in America.

Harrisburg and Chambersburg. An ordinary day-coach was divided into four compartments fitted with bunks against the side. In the rear the heavy-eyed passengers, who had vainly tried to sleep while the car bumped its way during the night over the uneven track, might wash themselves as best they could with the aid of the basin and towel there provided. To



Courtesy of the Pullman Company.

OLD NO. 9, THE FIRST PULLMAN SLEEPING-CAR.

A Chicago and Alton day-coach remodelled at Bloomington, Ill., by George M. Pullman, and first operated from there to Chicago in 1859.

undress was out of the question; there were no bedclothes. Men threw themselves down on mattresses and piled over them their coats and shawls. For almost a generation these "bunk" cars were all in the way of sleeping accommodation the various railway companies offered the public. Bedding was furnished after a time, each passenger proceeding to a closet at one end of the car, selecting the cleanest sheets and blankets he could find and making his own bed. At irregular intervals the bedclothes were washed.

One who often tossed about in "bunk" cars on his journeys between Buffalo and Westfield was a young contractor named George Mortimer Pullman. Westfield knew him at one time as a clerk in the country store, but lost sight of him when he joined his brother, a cabinetmaker, of Albion, N. Y. Business

was dull in Albion, and young Pullman cast about for money-making opportunities. He took the contract of moving some buildings to the banks of the newly widened Erie Canal, and thus it was that he acquired a first-hand knowledge of sleeping-car misery in the early fifties. Since Pullman was born in 1831, he was still in his twenties when the terrors of a railway night were thrust upon him. On one of these journeys he thought of a car in which it was actually possible to sleep, but it was not until 1855, after he had moved to Chicago, whither his boundless energy and restlessness had urged him, that he put his ideas to the test. He made some money by contracting to elevate some wretched sunken streets and raising buildings to the new level.

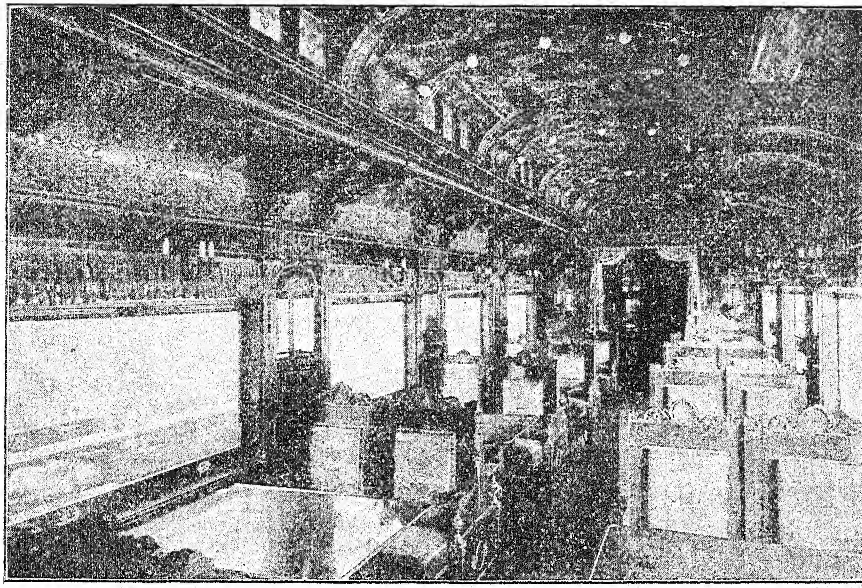
In 1858, three years after his arrival in Chicago, then an overgrown country town of about 100,000 population, he built his first sleeping-cars for the Chicago and Alton Railroad. He simply remodelled two old coaches, built into them ten sleeping sections, a linen-closet, and two wash-rooms. Pullman even then had notions about interior decoration. He finished his remodelled cars in cherry. Plans there were none. Pullman and a few men worked out the details and the measurements as they came to them. The two cars cost Pullman not more than $2,000, or $1,000 each. They were upholstered in plush, lighted by oil lamps, heated with box stoves, and mounted on four-wheel trucks. There was no porter in those days; the brakeman made up the beds. So little accustomed were the passengers to the luxuries provided that on the first night they had to be asked to take off their boots before entering their berths. Incidentally, it may be mentioned that the upper berths were of the swinging type ever since built into American sleepers—the invention of Pullman. Curtains, and not wooden partitions, divided the sections.

The cars proved a success after a few months' trial. To Pullman, however, they were merely old cars slightly improved, an experiment, and certainly not the luxurious bedrooms on wheels of which he had dreamed on his rough nightly journeys through the State of New York. It was not until 1864 that he built the first real Pullman car. Into it he put practically all the money that he had saved—over $20,000.

Twenty thousand dollars for a single car! Railroad men stood aghast at such extravagance. They had reluctantly spent \$5,000 after Pullman had shown them the way with his two experimental cars. It seemed impossible to make money out of the "Pioneer," as this \$20,000 venture was fittingly called. Moreover, the "Pioneer" was higher and larger than existing cars; the question was how to get it under the old bridges and past the more protruding platforms. But luck was with Pullman. The government engaged the "Pioneer" to carry the body of President Lincoln from Chicago to Springfield, for which reason one railroad had to adapt itself to Pullman's ideas of what cars should be. Later General Grant used the "Pioneer" for a journey from Detroit to Galena, Ill., and another road adapted itself to Pullman's car.

The increased dimensions of the "Pioneer" meant greater weight; hence Pullman added a third wheel to each truck. This introduced the three-wheel truck which has since become the standard for all Pullmans and heavy passenger-cars. While our modern cars are longer than was the "Pioneer," their width and height are the same. By standardizing construction Pullman helped to bring about the system which makes it possible for a man to travel in the same sleeping-car from one end of the country to the other.

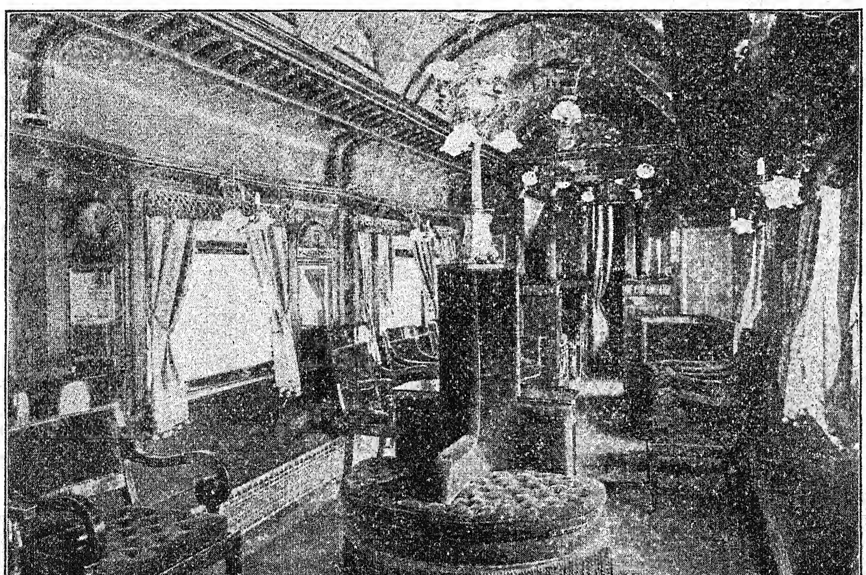
The immediate successors of the "Pioneer" cost Pullman about \$24,000. It was not yet proved that such an expenditure was justified by possible earning power. Pullman argued that any sensible traveller would be willing to pay two dollars a night for comfort, attractive surroundings, and the greater safety his cars afforded through their stanch construction. The railway managers were convinced that the prevailing rate of \$1.50 was the maximum that the public would pay. But at Pullman's suggestion the new sleeping-cars were coupled with the old in the same train, and it was left to the passengers to render a decision. Render it, they did. Only those who grumbled because all berths had been sold out for the new cars travelled in the old. Such was the demand for accommodations in the new Pullmans that the Michigan Central Railroad, convinced by the experiment, was forced to abandon the old-fashioned sleeper.



Courtesy of the Pullman Company.

THE DINER "AMERICA" EXHIBITED AT THE CHICAGO WORLD'S FAIR IN 1893.

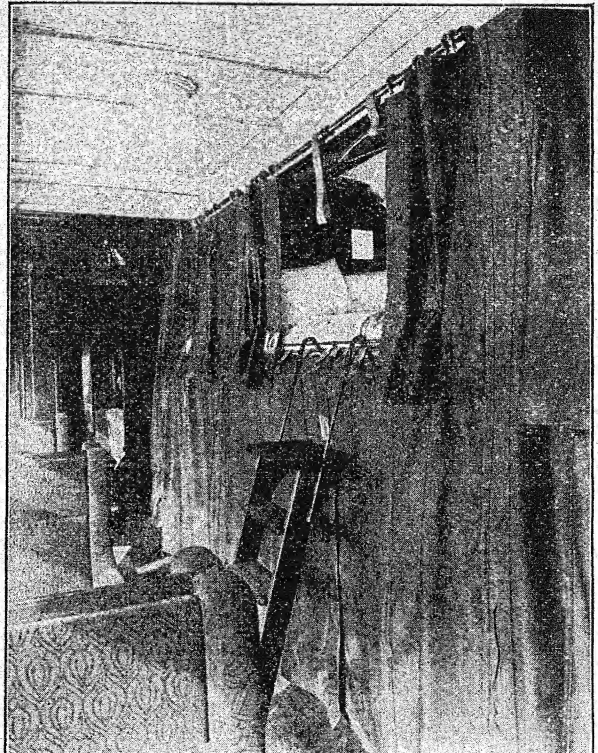
A perfect specimen of the rococo period of Pullman interior decoration.

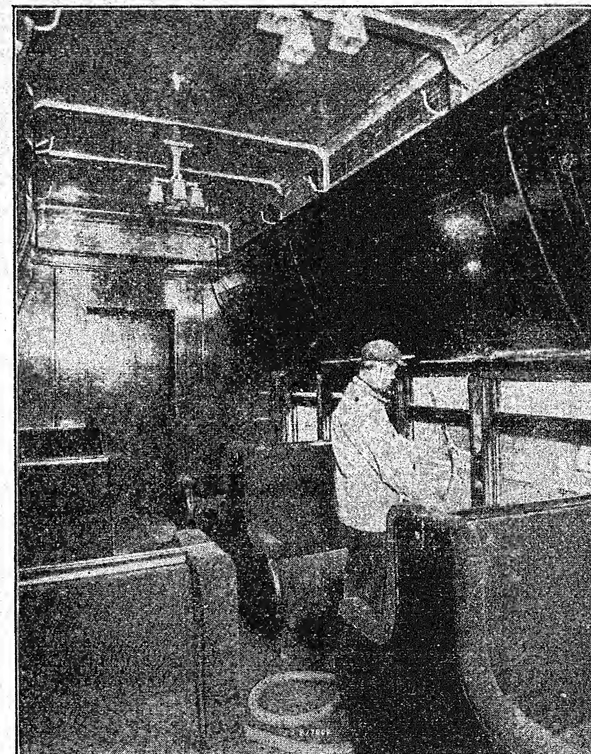


Courtesy of the Pullman Company.

PULLMAN'S "PACIFIC" COMBINATION SLEEPER AND OBSERVATION-CAR.

The "Pacific" was exhibited at the Chicago World's Fair in 1893 by the Pullman Company. A rococo tempered by time.



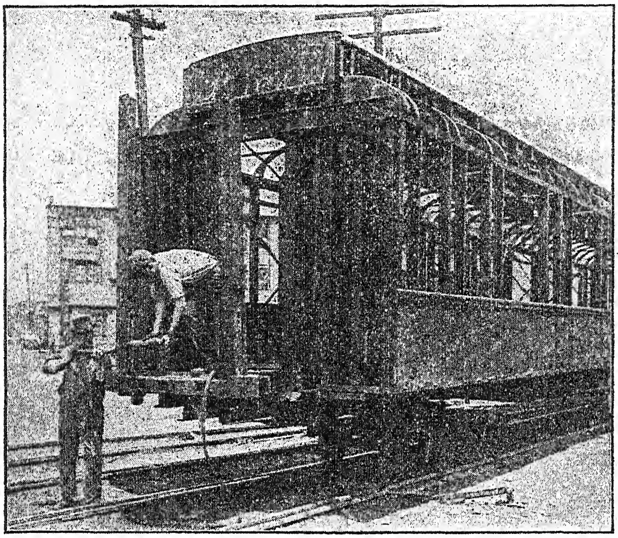


Courtesy of the Pullman Company.

INTERIOR OF A MODERN PULLMAN SLEEPING–CAR.

The bunk, or upper berth, of a modern Pullman sleeper ready for occupancy. The passenger's entrance or exit will not disturb the man below, the curtains being distinct. The gaudiness of the early Pullman sleepers has given place to a more pleasing simplicity. But the old principles which were invented by Pullman have been retained.

These early cars of the "Pioneer" type had all the characteristics of the modern Pullman sleeper. By day there was no sign of berth or bed. Every night the linen was changed. Enthusiastic reporters commented on the "window-curtains looped in heavy folds," "the French plate mirrors suspended from the walls," and the "beautiful chandeliers with exquisitely ground



Courtesy of the Pullman Company.

RIVETING THE I-BEAMS OF A PULLMAN CAR.

The four I-beams (two at the vestibule end, as shown, and two directly behind at the entrance) are of such strength as to make "telescoping" an impossibility. Like the willow, they give but do not break. In the case of an impact the adjoining car might climb but could not telescope this car.

shades" which hung from a ceiling "painted with chaste and elaborate design upon a delicately tinted azure ground." The old cars had bare floors. In the Pullmans the traveller's feet sank in Brussels carpet.

In 1867 Pullman owned forty-seven cars, all of them manned by negro porters and crews in accordance with a system that has since become part and parcel of the American railroad. He now introduced arrangements for serving cooked food. His first restaurant experiments were conducted in what he called "hotel" sleeping-cars, in reality sleeping-cars with kitchens at

one end. Meals were served at tables which could be quickly mounted in place and as quickly taken down. The idea of cooking and serving meals with hotel ceremony on a train originated with Pullman, and was first carried out in 1867 on the Great Western Railroad of Canada. These "hotel" cars cost $30,000 each, and out of them developed the Pullman dining-car without sleeping accommodations. The first of these "diners" was introduced in 1868 and was fittingly named the "Delmonico." Meals were served at one dollar each. Later came "parlor" cars and smoking-cars.

The necessity of passing through several coaches to the "diner" suggested the need for a safe, covered passageway. In 1887 the vestibule Pullman train appeared, in which the problem of allowing cars to sway and to round curves without tearing away the covered passage was solved. The patentee was not Pullman himself, but H. H. Sessions, one of his employees. Thus was the "solid-vestibule train" introduced, now the standard equipment of every self-respecting American railroad. The abutting faces of the vestibules terminate in flat, broad, steel frames, held against each other by stout springs. The vestibules not only tend to steady the cars, but also to shut out drafts, cinders, and dust. Moreover, in case of collision they prevent telescoping, and thus add to the safety of travel.

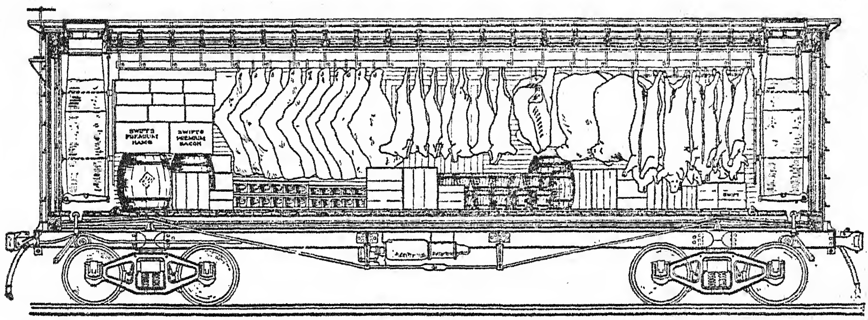
The American Freight-Car

The American freight-car is as distinctive as the passenger-car in respect of size, weight, and carrying capacity. The larger the single unit of transportation, the lower the cost per ton of the freight carried, and the great size of our freight-car is one of the reasons why American railroads can profitably move freight at a lower rate than the European roads.

American cars are of three principal types: the flat car, the closed box car, and the coal car; although each of these include subtypes, designed for special service. The most notable growth in size is found in the coal cars, particularly those of the hopper type, with hopper bottoms, closed by hinged doors or gates, which on being released, instantly discharge the whole contents. During the past forty years these have increased, successively, to capacities of 25, 50, 75, 100 and, during the past year, to 120

tons of coal—the last-named being carried on three-wheel end trucks.

Of the special cars, none has shown a more remarkable development than the refrigerator-car, designed for the carrying of dressed meat from the great Western packing-houses to the various cities throughout the Eastern States—a development



Courtesy of Swift and Company.

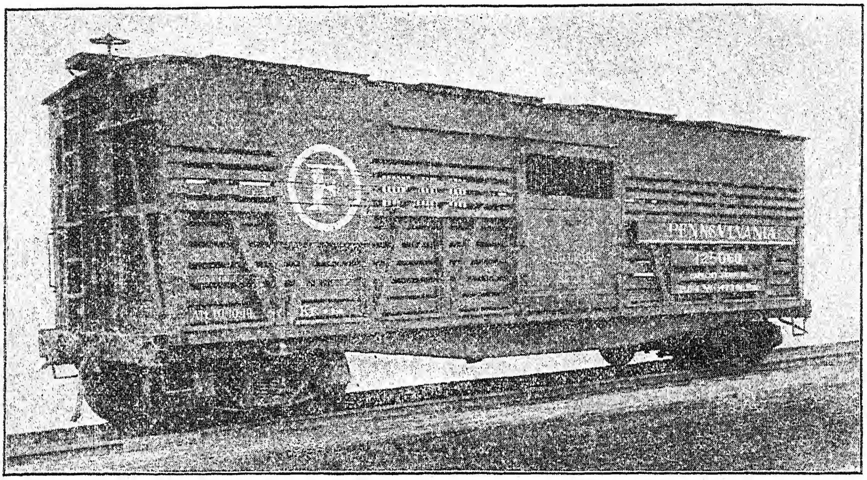
INTERIOR OF A SWIFT REFRIGERATOR-CAR.

An invention that enabled the packing industry to centralize the killing of cattle and to reduce the cost of meat.

mainly due to the foresight and enterprise of Mr. G. F. Swift, the founder of Swift and Company. Before the introduction of the refrigerator-car, live stock was shipped "on the hoof" from the distant Western ranches to the packing-houses in Boston, New York, and other Eastern cities. Swift realized that if the animals were slaughtered, say in Chicago, and the dressed beef were shipped from there to the Eastern cities, there would be a considerable reduction of freight expense, meaning cheaper meat to the consumer, and the ill-conditioning of live stock by a long, overland journey would be avoided.

So in 1875 he developed a box car of special construction in which the dressed beef and pork were hung from the roof, and the floor space was filled with other products such as lard in tubs. To keep the meat at a constant low temperature, he provided end compartments, or bunkers, in which was placed cracked ice and salt. The chilled air flowed downward to the floor and then up through the car to the roof, where it passed out through ventilators.

The refrigerator-car was a success from the first. But the railroads refused to build the cars themselves and the packers had to construct their own rolling-stock. To such proportions



Courtesy of the Pennsylvania Railroad.

MODERN AMERICAN LIVE-STOCK CAR.

The American freight-car is as distinctive as the passenger-car in respect of size, weight, and carrying capacity. The present tendency is toward steel construction. This standard live-stock car has a steel underframe.

has this enterprise grown, that Swift and Company alone employ 8,000 refrigerator-cars to transport their products.

Safety in Railway Travel

The loud protests against the danger of railroad travel, with which the first proposals to carry passengers at the unheard-of speeds of from fifteen to thirty miles an hour were received, were not so unreasonable then as they seem to us to-day. It was one thing to start a train and speed it up to thirty miles an hour—it was quite another thing to stop the train when some obstacle ahead, some defect in the track, threatened destruction.

A train of the twentieth century, made up of a 250-ton locomotive and 10 cars of 75 tons each, running at 60 an hour, in a collision would strike a blow equal to that delivered against armor-plate by the 2,450-pound projectile from our biggest

army gun—the 16-inch coast-defense gun which was tested at Aberdeen, Maryland, in 1922.

So, having learned how to start and speed up a train, the next thing to learn was how to stop it in the face of danger, and stop it in the least possible distance.

Robert Stephenson, the gifted son of George Stephenson, realized this, and in 1843 he devised a steam-brake, in which a steam-cylinder, acting through levers, pressed two wooden blocks against the driving-wheels. The invention was ahead of its day, but the principle, with air substituted for steam, is in use on all modern engines.

The early braking arrangements, both in England and America, were very crude. On the New Castle and Frenchtown road in the United States the trains were stopped by main physical strength with an enormous hullabaloo on approaching the station at the signal of the engineer. He raised his safety-valve, and the sudden loud hissing noise thus produced summoned negro slaves who rushed to the train, seized it, and tried to hold it back while the station agent thrust a stick of wood through the wheel spokes. Better than this was the more commonly used hand-brake for passenger-trains, and the foot-brake for freight-trains. But even with these the shock of stopping was enough to shake every bone in the body of a passenger or a trainman.

Later, the rotating axles of the cars were made to wind up chains which pulled on the brakes. Next, the motion of closing up the cars as they thrust in the draw-heads by which cars were coupled, was utilized to wind up the chain brakes. Then the steam-brake and the vacuum-brake were tried. All of this experimental work led up to the conviction that any effective braking system must be *continuous*—that is to say, every wheel of the train must be braked simultaneously by one man from one point on the train. This man, of course, was the engineer in his cab.

The Westinghouse Air-Brake

The problem was solved by the genius and perseverance of that great American inventor, George Westinghouse. The facts of his stirring life and the underlying principles of his invention

are given in the chapter "Putting Air to Work." On the locomotive Westinghouse provided a steam-driven air-pump, which maintained a constant air-pressure of seventy pounds in an air-reservoir also located on the locomotive. From this air-reservoir an air-pipe led up to a control-valve near the engineer's hand. From the control-valve an air-pipe, now known as the "brake-pipe," was led beneath the floor of the cars for the whole length of the train. Also, attached below the floor of each car, was a brake-cylinder. The piston-rod of this cylinder was so connected to the brake rods and levers—"brake-gear"—that when air was admitted, the movement of the piston, acting through the brake-gear, would set the brakes. When the engineer wished to slow down the train or stop it altogether, he opened his valve. The air rushing through the brake-pipe entered the brake-cylinders on each car and set the brakes.

So far, so good. But it took time for the air to fill all these cylinders. Those next the engine were filled first, and on a test, it was found that the last car was not braked until eighteen seconds later. This was too slow for an emergency.

Then Westinghouse did a very clever thing. He placed an air-reservoir on each car and kept it filled at all times with air. Between this reservoir and the brake-cylinder he placed a most ingenious device known as the triple valve. He maintained the train-pipe under air-pressure. The triple valve formed the passageway between the auxiliary air-reservoir on each car and its brake-cylinder, and this valve, normally, when the brakes were "off," was closed and was kept closed by the pressure in the brake-pipe. It was so adjusted that when the brake-pipe pressure was reduced it would open, permitting air to pass from the reservoirs on the cars to the brake-cylinders. This action was instantaneous.

Now see how beautifully the device operated. All the engineer had to do to set the brakes *simultaneously* throughout the train was to open his controlling-valve and let air out of the brake-pipe, lowering its pressure throughout the whole train. This caused the triple valves *instantly* to pass air from the car-reservoirs to the brake-cylinders, so that there was a practically instantaneous application of the brakes throughout the train.

To demonstrate his brake George Westinghouse equipped a

train of 50 freight-cars and ran it 3,000 miles around the country. In comparative tests, hand-brakes stopped the train when running 20 miles an hour in 794 feet. The air-brakes stopped the same train in 166 feet.

The next improvement provided an extra or emergency reservoir on each car, which could be opened so as to add an additional brake pressure for a quick stopping of the train in an emergency.

Finally, it was considered important to secure an *equal* pressure on all brakes throughout the train. Unequal pressures produce heavy surging and jerking effects, which are destructive to the cars and extremely annoying to the passengers. This was accomplished by the introduction of the automatic straight air-brake. With this brake a coal train of 100 cars weighing with the engine about 9,000 tons, was taken down a mountain grade at a predetermined low speed, without any jerking or surging of the cars.

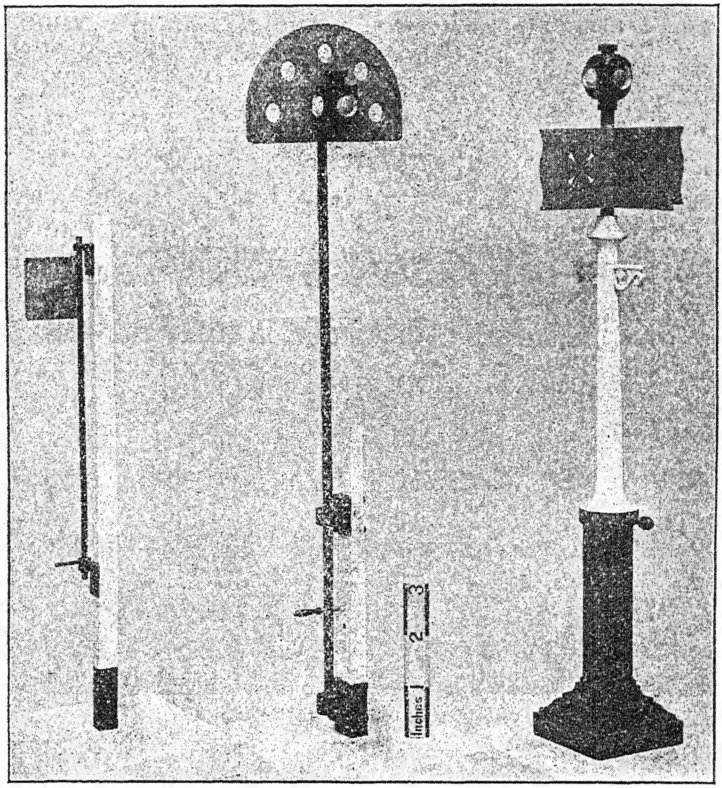
Signalling Systems

A railroad must not only have a method of stopping its trains, but it must know *when* to stop them. The necessity for signals, both to warn the engineman of dangers ahead and also to tell him whether the track is clear, was realized from the very first. Stephenson sent a man ahead with a flag to warn vehicles and foot-passengers, and the early trains, here and in England, utilized the horn of the stage-coach guard. In America this was eventually superseded by the bell and steam-whistle; but the former is more ornamental than necessary to-day.

Signals are of two kinds: those which protect switches, junctions, and railroad crossings, and those which preserve a safe interval between trains running on the same track. The latter are known as "block-signals."

In the days of the single-track road the "staff" signal was used. There was a single staff for each stretch of road between any two stations A and B. No train was allowed on that "block" without the staff that travelled back and forth and never left the block. A train reached Station B. The station master handed the staff to the engineer. He carried it to A and handed it to the master there. It was carried back to B by the first

train running in that direction. Since there was but one staff, two trains could never be in the same block at the same time. The method was safe but crude. By that arrangement a col-



Courtesy of the South Kensington Museum.

MODEL OF LIVERPOOL AND MANCHESTER RAILWAY DAY AND NIGHT SIGNALS.

This represents the earliest form of fixed signal, introduced on the Liverpool and Manchester Railway about 1834. It consisted of a rectangular frame on which a red flag was stretched, fixed to a vertical rod which was mounted in bearings attached to a wooden post. By means of a handle near the bottom the flag could be turned so as to face the engine-driver, when indicating danger, or set parallel with the rails to indicate safety. Red and white lights placed on posts served the same purpose at night.

lision between stations was avoided, since two trains could not be in possession of the same staff at the same time.

The first system of fixed signals was introduced in 1834 on the Liverpool and Manchester. It consisted of a post with a rotating disk at its top, showing red for danger. The absence

of the red by day or the glow of a white light at night indicated that the road was clear. Sir Charles Gregory in 1841 designed and erected at New Cross the first semaphore signal. There was no communication between stations; each signalman displayed his danger-signal after the passage of a train until a certain time had elapsed.

It is said that the modern method of operating semaphores by wires or shift-rods was the offspring of laziness. About Gregory's time, an unknown English railway "pointsman," who had to attend to two station signals, decided to save himself the trouble of walking to and fro between them by fastening the two levers together with a long piece of wire. A broken chair served as the counterweight. The wire ran into his hut, where he sat by his fireside and worked the two signals without setting foot outside. When his method was discovered he was reprimanded by the railway authorities, promoted, and rewarded for his ingenuity.

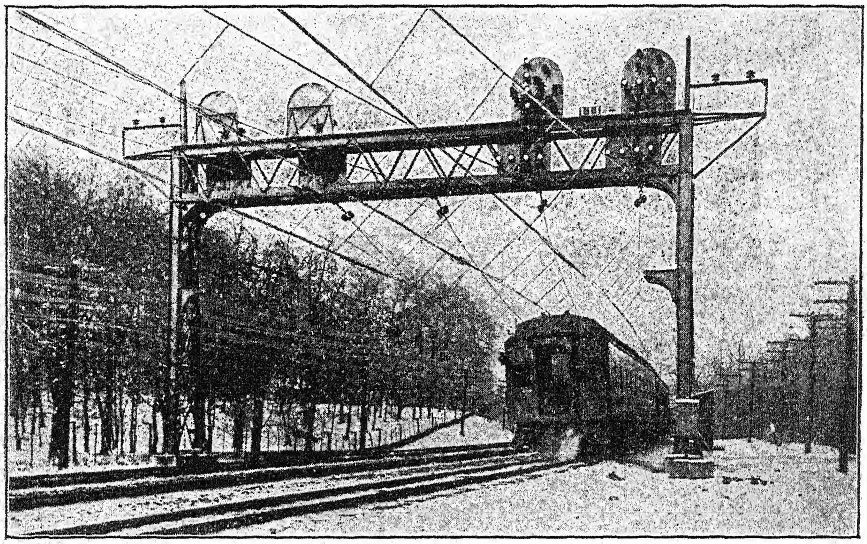
But it was evident that the semaphore system considered only the *time* interval between trains. The signalman had no means of knowing whether the train had stopped or not before it had reached the next signal. The telegraph remedied this defect.

Sometimes the signalman would not act promptly enough, and sometimes he failed to act at all. The consequent collisions led to the installation of devices to give advance information to the engineman of the position of the signal that he was to obey, and this was the inception of the block-signal system of our day. Next to the automatic air-brake the block-signal system is the greatest safety device of the modern railroad.

The "Bell Code," as it was called, was introduced on the Southwestern Company of England by C. V. Walker—the first audible method of communication between signal-stations. This was supplemented by electric visual signals, the glowing of a light informing the signalman whether a signal had been displayed. Here we have a suggestion of space interval between trains, something better than the untrustworthy time interval. By 1858 the positive block system, based on the space interval, was established in England. In the block system the road is divided into "blocks" of various lengths, the minimum length

being that within which the brakes will stop the train. No two trains are allowed in the same block at the same time

The United States proceeded along different lines. Ashbel Welch, chief engineer of the United New Jersey Canal and Railroad Company, devised and installed in 1863 the first block



Courtesy of the Pennsylvania Railroad.

MODERN ELECTRIC SIGNAL BRIDGE.

The electric signal over the right-hand track reads "Stop." This means that the westbound train here shown, near Rosemont, Pa., has just entered a "block" of 3,500 feet in length. The signal will remain at "Stop" until the train enters the next block, when it will go to "Caution," with the diagonal, instead of vertical, row of lights lighted on the upper half. On the adjoining westbound track, shown in the picture, the signal reads "Proceed," which means that at least three blocks ahead are clear.

system of signals in this country on the double-track line between Philadelphia and New Brunswick. He made use of telegraphic communication. The signalman did not remove the red danger-signal after a train had thundered by until he had been advised by telegraph that the next station had been passed. This telegraph block system, with modifications, is still generally used. The addition of track circuits for locking and indicating purposes, and for interlocking between stations, was effectively brought about by the Coleman block instrument in 1896, and from this was developed the controlled manual block system used to-day.

The development of interlocking prevented the display of conflicting signals. In the interlocking system the entire control of switches and signals in a large terminal is assigned to one man equipped with a machine that cannot possibly indicate conflicting routes. In this England, as usual, led. Ashbel Welch, after convincing himself of the advantages of interlocking as practised in England, recommended its adoption here, and thanks to his efforts the system was introduced in the United States in 1874. Power-operated interlocking systems followed, and the more recent development of power-operated interlocking systems has made it possible for larger railroads to consolidate control in a central station.

But signalmen are but human. What was really wanted was a method of making the train itself operate the signals. The need was early recognized. In 1867 Thomas S. Hall patented an electric signal which was used in connection with a switch or a drawbridge. It was defective because a break in the circuit gave no indication of danger. Thereupon he devised a closed-circuit system. In 1870 William Robbins hit upon the plan of having the wheels of the locomotive push down a track-lever which closed the circuit and cleared the signal, unless there was a break in the line.

It was Hall who introduced the first American automatic electric block system and installed it on the New York and Harlem Railroad. The wheels struck a lever to complete a circuit and set the danger-signal, and held it in that position until the train had reached the next signal or "block." But there were disadvantages in causing a train moving at high speed to strike a lever; the blow delivered was terrific. So, F. L. Pope devised a system in which the track itself acted as the electric conveyer, the wheels and axles completing the circuit and throwing the signal to danger. In 1879 this invention was introduced in service, and to some extent is still in use. Then followed systems in which both electricity and compressed air were used. In these electropneumatic systems the signalman threw over a little lever or switch and immediately, by means of magnets at the far-distant semaphore, the control-valve of an air-cylinder was opened and moved the signal-arm.

The latest safety device is the automatic train-stop. So

many are the inventors who have devoted their lives to this phase of railway signalling that it would be impracticable to enumerate them here. Each contributed something, so that the modern automatic stop is hardly to be credited to a single man. All these systems operate on much the same principle. A downwardly projecting contact rod is mounted on the locomotive so as to touch a short length of raised rail in the middle or at the side of the track. This short rail is in electrical circuit with the signal. When the signal is at "danger" an electrical impulse passes through the rail and locomotive contact rod and sets the brakes. The automatic stop is not fully perfected, but already it has probably saved thousands of lives.

Linking the Atlantic with the Pacific

In the expansion of the country westward of the Alleghanies, more formidable than the bloody opposition of the Indians was the lack of means of adequate transportation. It was in this development of the West that the railroad was destined to play a conspicuous part. At first the settlers were almost entirely dependent on wagons and such navigable streams as the Ohio and the Mississippi. A few products, such as hides, furs, and ginseng, could be sent East by pack-horses and wagons; hogs, cattle, and horses could be driven "on the hoof" over the mountains; but most produce had to be circuitously transported by water. The population of Ohio, Indiana, Illinois, Michigan, Wisconsin, and Iowa had increased from 50,240 in 1800, to 792,719 in 1820, and to 2,967,840 in 1840. "We are great," said Calhoun in 1817, "and rapidly—I was about to sav fearfully—growing."

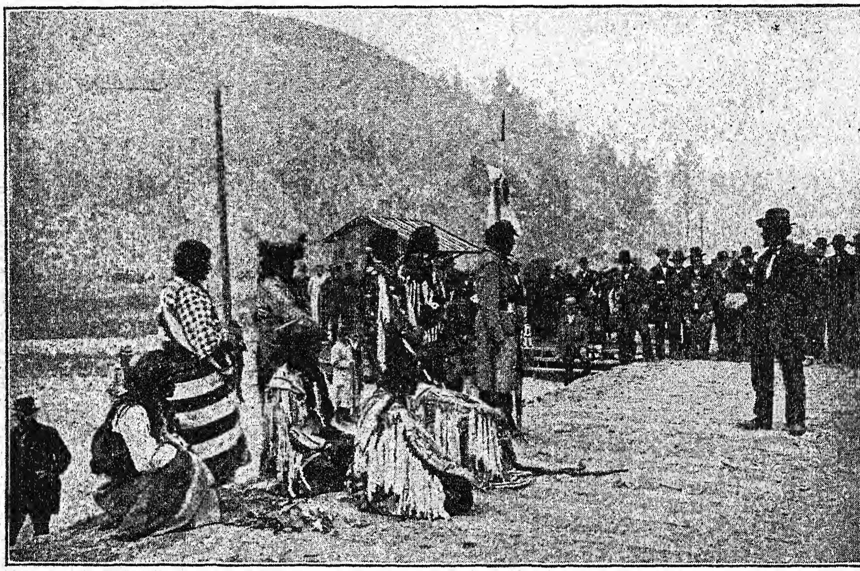
It was vitally essential that the railroad should bring this rapidly growing population in contact with the Eastern seaboard. The steamboat had done well, but at its best it was indirect transportation down rivers and round by way of the sea. The United States has seen three periods of transportation which are thus classified by Bogart in his *Economic History of the United States:* the turnpike period; the river and canal period; and the railroad period. By 1850, however, the railroad had assumed the ascendancy, and the development of the Far West was now assured.

The discovery of gold in California in 1848 drove home to the American people the importance of transcontinental transportation. When stories drifted East that one man, with the help of a few Indians, cleared a dollar a minute; that "panners" earned as much as $5,000 a day; that nuggets worth thousands of dollars were being picked up by boys, the rush to the West began. There were just two ways of reaching California: by a rough and dangerous voyage around Cape Horn, or by the still rougher and still more dangerous overland route in canvas-covered wagons drawn by mules or oxen. Probably never in history had so many people been eager to travel to an unsettled land. Thousands who journeyed by wagon died of hunger or hardship, or were killed by Indians. The overland trail was marked by the white bones of gold-seekers.

Those who arrived in the Promised Land found it harder to earn a living than they had been led to believe. Spades and shovels cost $10 each. Flour sold for $400 a barrel. Even a wooden bowl for washing gold cost $16. A San Francisco restaurant charged $3 for a cup of coffee, a slice of ham, and two eggs. A month-old newspaper was worth a dollar.

There was a crying need for transportation. The canvas-covered "prairie-schooner" was introduced, an improvement over the older ox-drawn wagons, a huge vehicle drawn by six or twelve animals, the whole costing from $3,600 to $7,000. But it took from May to November to cross the prairie to California in these wagons. For the carrying of mails, express packages, and passengers, stage-lines were organized. In the stage-coach of 1858, eleven passengers, by travelling night and day, could reach San Francisco from St. Louis in a little more than three weeks at a cost that varied from $100 to $600. Even this faster method of transportation was too slow for important despatches. At the suggestion of Senator Gwin the pony-express was established in 1859, with 500 horses, 190 relay stations, 200 hostlers, and eighty first-class riders, among whom the famous "Buffalo Bill" was soon numbered. Letters had to be written on tissue-paper, and the postage at first was five dollars for less than half an ounce. Yet even these expert, lightly armed riders took ten days to travel from Missouri to the Pacific coast.

The need for transportation across the continent became so urgent that the idea of a railroad stretching from coast to coast took ready root. The government authorized extensive surveys. For years Frémont and others explored the mountains seeking the most favorable roadway. Congress received petitions, memorials, and letters urging the establishment of a rail-



Courtesy of the Northern Pacific Railroad.

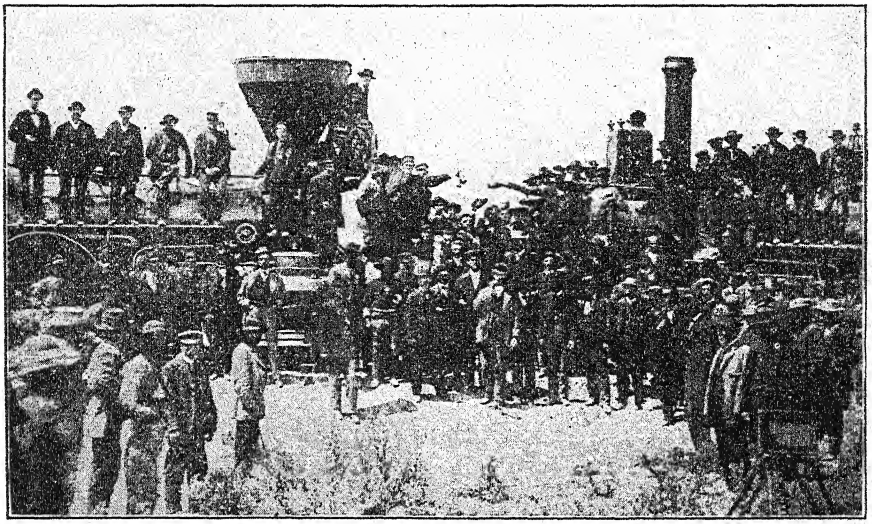
BUILDING THE NORTHERN PACIFIC RAILROAD.

Driving the last spike in the transcontinental system in August, 1883, under the direction of Henry Villard, at that time president of the Northern Pacific.

road. The bitter feeling that finally brought on the Civil War retarded progress; for the North wanted a northern route; the South, a southern route. Yet so pressing was the need that even in the midst of the war the project of a transcontinental line was not entirely forgotten. After a lengthy debate Congress, in 1862, voted in favor of incorporating the Union Pacific Railway Company. This was to be the eastern company to connect with the western Central Pacific Railroad of California. President Lincoln lent his powerful support to the enterprise, and chose Council Bluffs, Iowa, as the eastern terminus. The

Central Pacific Company began work at the California end and turned its first sod on Washington's Birthday, 1863.

After the Civil War the energies of the country were redoubled in opening up the unsettled portions of the West and in linking the Atlantic with the Pacific. General Sherman became an ardent advocate of the railroad, and General Dodge,



Courtesy of the Union Pacific Lines.

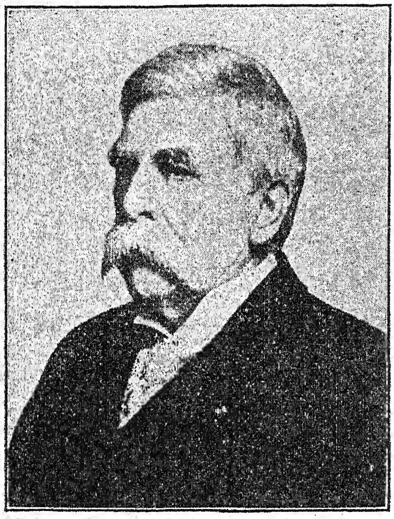
WHERE THE UNION AND CENTRAL PACIFIC MET.

Completion of the work which united the Union and Central Pacific lines. The engineers shake hands.

a great soldier-engineer, took charge of the work. It was harder to build the eastern than the western end of the line because of lack of material. For two years building material, workmen, equipment, had to be brought up the Missouri River by steamer or across the plains by prairie-schooner. Indian tribes frequently descended on the railway-builders, but meat at least was plentiful. General Sheridan states that on one occasion he rode for three days, in 1868, through a single herd of buffalo.

Unfortunately, progress was so slow that at the end of one year the Union Pacific had laid but 40 miles of track, and after five years the Central Pacific had completed only 136 miles. To stimulate the companies Congress offered a bounty

of from \$64,000 to \$96,000 a mile for work done in the mountainous country. Then began a contest between the Western and the Eastern companies. In 1868 the Union Pacific had built 425 miles, and Central Pacific 363 miles. The following spring the road was complete—all but the actual meeting of the two branches. Congress failed to designate where the roads should join; so the rival companies, to earn the rich bounty, simply kept on building, although their lines were paralleling each other. The Central Pacific had built eighty miles beyond Promontory Point, near Ogden, Utah, the junction finally agreed upon, and the Union Pacific had spent a million dollars in needlessly pushing on beyond Ogden. The last ties were laid on the 10th of May, 1869, by the Chinese of the Western company and the Irishmen of the Eastern company. The final tie was of polished California laurel, to which the rails were secured by spikes of silver from Nevada and Idaho, spikes of gold, silver, and iron from Arizona, and a spike of gold from California, all driven in by a silver sledge-hammer. The blows of that hammer were heard in the East by the aid of telegraph-wires attached to the rails. Such was the public excitement that according to one writer "Chicago made a procession seven miles long; New York hung out bunting, fired a hundred guns, and held Thanksgiving services in Trinity; Philadelphia rang the old Liberty Bell; Buffalo sang the 'Star-Spangled Banner,' and many towns burnt powder in honor of the consummation of a work which . . . gives us a road to the Indies, a means of making the United States a half-way house between the East and the West, and last, but not least, a new guaranty of the perpetuity of the Union as it is."



Courtesy of the Union Pacific Lines.

GENERAL GRENVILLE M. DODGE.

Chief Engineer of the Union Pacific Railroad during its construction.

Eighteen hundred miles of track from the Mississippi to California had been laid through a wilderness, and a vast amount of tunnelling and bridge-building had been completed, the whole at an expense to the government of $830,000,000. The building of this transcontinental railroad is the greatest feat in the history of American engineering, with the possible exception of the construction of the Panama Canal.

Statistics

This, then, is the story of the American railroad. Like most American enterprises it is a story of big things, done in a big way, by big men. If we could unravel the network of the shining steel rails which cover the forty-eight States of the Union, stretch it out to a single line, and wind it around this earth, we could circle the globe ten times and still have 20,000 miles to spare. If we could assemble all the 69,000 locomotives, 57,000 passenger-cars, and 2,500,000 freight-cars and couple them up, end to end, they would fall only 1,000 miles short of forming a complete girdle around the earth at the equator. Finally, if we were to assemble all the railroad employees for a grand parade in New York, we would have an army almost the size of the one we sent to France in the war, roughly 2,000,000 men. If that parade, in ranks stretching from curb to curb, or sixteen abreast, passed a reviewing-stand in New York, it would take fully three days and nights before the last rank had gone by.

To build this stupendous system has cost $20,000,000,000, or as much as the whole cost of the war. There are men living to-day who can remember the time when not a mile of this track and not a locomotive or car was in existence, for the American railroad is only ninety years old.

CHAPTER II

HOW POWER WON THE INLAND WATERS

Early Methods of Transportation

THE winning of the waters in the interior of the region now known as the United States brought about the real union of the commonwealths which, in 1776, had declared themselves free and independent peoples. This union would have been delayed many years, however, had it not been for men who in their youth saw a vision which gave them no rest until it was realized. Despite many discouragements, and often in the face of criticism, they held to their ideas until widely scattered communities were connected by the bonds of trade and traffic and the future of the country was assured.

Although Americans were once famed as a sea-faring race, they did little for many a decade to promote the navigation of their big rivers and Great Lakes. Their clipper ships were seen in the ports of Europe and in the harbors of China long before the taming of their own Mississippi. They turned their daring and skill in the direction of the arctic circle in quest of whales, and gave battle to the pirates of the Spanish Main, leaving their vast waterways of the West unexplored.

Strange as this situation may seem, it was the natural outcome of the conditions under which the colonies were founded. At first, the settlers built their homes either on the ocean or on the banks of the navigable streams which flowed into it. They kept in touch with one another by voyaging in pinnaces and sloops along the coast, making the deck answer the same purpose as the wagon or coach. In New England there developed the "Apple Tree Fleet," made up of schooners, the skippers taking their bearings from the orchards along the ocean beaches. Then came stout barks and full-rigged ships, which essayed the trade of the West Indies and finally sought the Big Ferry which brought them to foreign shores.

In due time the early colonies were assembled about water routes directly connecting with the sea. Virginia flourished on the banks of the James; Maryland had the Potomac; Pennsylvania came into being on the shores of the Schuylkill and the Delaware, and the Dutch founded their New Amsterdam where the Hudson poured into what is now the harbor of New York. The value of land was largely rated by its distance from a wharf. If it had a ready outlet to the water, it was worth from ten to forty dollars an acre; if not accessible by boat, it might be worth only a few shillings.

It was hard work for the colonists to take themselves from place to place, but the transportation of goods was much more difficult. Many things were bought in England which might have been obtained on this side of the ocean. As an example of what it meant to go from one city to another, read the journal of Benjamin Franklin, who at the age of seventeen started out on some American touring. He set sail from Boston, in 1723, in a sloop bound for New York. Unable to find employment there, he started for Philadelphia, but was wrecked in a heavy gale on the coast of Long Island. Finally, he reached Perth Amboy, N. J., in a crazy little craft on which he had been thirty hours without food. He then walked across New Jersey to Burlington on the Delaware River, from which point he got passage in a rowboat to the town of William Penn. There he arrived, wet, bedraggled, and friendless, with naught to bless himself but a Dutch dollar.

Like other boys of his time, Franklin had been thrilled by the life of a sailor and had come very near defying the will of his father and going before the mast. This taste of the temper of the ocean may have had a good effect. Years later Franklin became assistant postmaster-general for the continent, and he made a study of transportation, both by land and water. His early travelling experiences therefore were very valuable to him, as well as to the nation.

Inland, most of the communication was by canoes made after the fashion of the original Americans, who were given to painting their faces and unpleasantly wielding the tomahawk. These aborigines made canoes by hollowing tree trunks, but the common type of boat among them was the birch-bark

canoe, which was so light that it could be carried easily from one stream to another. The eighteen-inch paths through the primeval forests, the Indian trails, were merley passages through which "poor Lo" could carry these frail craft from one river to another. The white men, when they essayed the inland wilderness, also adapted themselves to this method of transportation.

In 1760 Franklin wrote that the western country of America was accessible by great interior rivers and lakes, except for the shortest portages. He said it was possible to go from New York city to Lake Ontario by water, with the exception of a break of twenty-seven miles over which it was necessary to carry canoes. From Lake Erie stretched hundreds of miles of water passage into the heart of the Rockies. From Canada, the Hudson valley, the St. Lawrence, and the lakes George and Champlain furnished a liquid highway used by Iroquois and Algonquins both in peace and war—as all of us who have read the novels of James Fenimore Cooper well remember. That there was an internal commerce over these trails, portages, and streams is known to every one who has studied the arrow heads and the wampum of the Indians; for weapons of iron and copper were brought from the Northwest to the East in the course of that primitive traffic. When Columbus and his caravels reached these shores, he found a land without horses, cattle, or beasts of burden of any kind, except a few dogs. Such a thing as a wheeled vehicle was entirely unknown. Transport in any large way was dependent upon water-courses, and upon the almost imperceptible paths made in the woods by lightly moccasined feet. Many years passed before the coming of the turnpike or of any other highway of the land.

Washington and Inland Navigation

Statesmen who charged themselves with the future of this country saw that, in order to weld the colonies into a whole, it was necessary to solve the problem of transportation. None sensed this more clearly than did George Washington. By instinct a frontiersman, by training a leader in commerce and finance, no man had been brought up in a more useful school of experience than he. Like Franklin he had an early longing

for the sea, which he overcame only at the instance of his widowed mother, who prevented him from accepting a commission which a relative had obtained for him in the British navy. The plantation where Washington was born was on Pope's Creek, a branch of the Potomac. In his boyhood he had learned how to handle the canoe and the skiff. As a young militia lieutenant he had served with General Braddock in the ill-starred expedition to western Pennsylvania, and had often tested the temper of forest streams. Once he narrowly escaped from drowning when he was hurled from a raft into deep water. Braddock, who insisted not only on wagons to take him into the wilderness, but also on the building of corduroy roads, was a commander of a school which had nothing in common with the needs of a land of pioneers. Washington, a surveyor in Virginia, had made a detailed study of transportation, and had set his heart on giving easy means of communication to the land which was the hope of the Western world. In all manner of water-craft he was master, as was shown by his crossing of the Delaware in the dead of winter to surprise the British at Trenton, and by his orderly retreat by boat from the city of New York when it was necessary to abandon the city to the British. And when the Revolution was over General Washington devoted himself to the development of his long-cherished plans of uniting the new nation in the bond of water-borne traffic.

This was no sudden impulse. The same idea had guided Washington in 1763, when he organized the Mississippi Company for the promotion of the lands of the West. Six years before the signing of the Declaration of Independence Washington had spoken of the need of bringing the watersheds of the East, with the Ohio River and the Great Lakes, into one system of communication. While at Newburgh, although the formal treaty of peace with Great Britain had not yet been signed, his alert and practical mind was busied with vast inland transportation projects for the new nation. He took a journey to the headwaters of the Mohawk and the Susquehanna, and, in 1783, started on his exploration of the West with the intention of achieving an ambition which he considered of such importance that he had declined an invitation to be the honor guest

of France. One of the many signs of his activity was his presidency of a canal corporation organized for the purpose of uniting the waters of Chesapeake Bay with the turgid floods of the Ohio River.

The time had come for abandoning old methods of travel and traffic. From the capital of the nation it was only a dis-

CHANCELLOR LIVINGSTON.

ROBERT FULTON.

Chancellor Livingston went to France as minister of the United States. In Paris he met Fulton, with whom he later formed a partnership. Livingston, member of an old, aristocratic family and one of the richest men of his time, had tried to build a steamboat as early as 1798.

Although he was a painter of miniatures, Robert Fulton had dreamed of steamboats even as a boy. He conducted experiments on the Seine in France and there met Livingston. Out of the friendship thus born came the successful *Clermont*.

tance of 150 miles to what one of the chroniclers well called "a most howling wilderness." The signing of the Ordinance of 1787, throwing open the vast domain of the Mississippi and Ohio Valleys to immigration and settlement, started an exodus to fields and pastures new. The Connecticut Yankee was glad of the chance to pack up bag and baggage and take his family for a hazard of new fortunes into the vaguely known "Empire of the West." Large grants of land to the officers and the soldiers of the army of the Revolution also hastened the movement toward the setting sun. At Marietta comrades in arms at Valley Forge were united on the banks of the storied Ohio. There was given to a huddle of huts lower down the stream the title of Cincinnati, in honor of the society in which so many of

the generals and colonels and captains of the patriot army had enrolled.

The migration across the breadth of the country was favored by the fact that the Ohio River had a westerly course, distinguished from the other streams which flowed south. The pioneers, therefore, made their way through mountain gaps and dense forests or over roads unworthy of the name, to Pittsburgh and other points at the headwaters of the Ohio. There they rested from their exhausting pilgrimage and prepared for the risks of the river. Their camps were made close to the Allegheny and the Monongahela Rivers which join as sources of the Ohio. Here had sprung up an industry unique in all history: the building of strange boats adapted to the passage of the swift and muddy streams of the central United States. In that region, Jacob Yoder, a German, had launched, in 1750, the first flatboat, an awkward box-like craft, drawing little water, on which he had committed himself and his goods to the crooked stream which forms the southern boundary of the Buckeye State.

The goal of the new traffic was New Orleans, then in the grip of the "power that was Spain." From that Gulf port, at the outset of the struggle of the colonies for independence, two soldiers had brought a flat-bottomed ammunition-boat which they poled up the Mississippi and the Ohio as far as the falls opposite Louisville. Owing to the low stage of the water, they could not get over the barrier, and they were obliged to carry their 136 kegs of powder for the Continental Army overland.

As the migration down the two streams increased, there developed a new class of human beings: the rivermen. Knowing the quirks and turns of the Ohio and the old "Massassip," they hired themselves out as pilots and guides to venturesome Easterners. The settlers bought or built flatboats, as the roofed scows were called, and with the guidance of the rough-and-ready Charons, they started on their voyages. In the craft they stowed all that they had, household goods, timber for their new houses, cows and horses and chickens, their cats and their dogs. When they reached places where they had arranged to rear new homes, they either sold their flatboats, or broke them up to get the material for their cabins. Some of the craft even

carried sawn lumber, loosely joined in a roof, which could be broken up easily and joined in the lodges "in the vast wilderness."

As the population of the Northwest Territory increased, the hardy farmers were able to move some of their products to the markets at New Orleans by the river routes. They raised hogs and corn in plenty, wheat, and barley. Some built their own grist-mills and turned out a flour, for which there was soon a European demand. Before the coming of the river transport, about the only commodities of that region which brought high enough prices to justify the heavy wagon rates were saltpetre, found in the caves of Kentucky, and the ginseng of Tennessee, which then, as now, was highly prized as a medicine by the Chinese. Before the new inland navigation began, the few farmers who had settled in that part of the country raised only enough wheat and meat and other products to feed their own families. The age of the flatboats, however, ushered in both agriculture and commerce.

Of all of that great fleet of flatboats built to serve the trade of the central United States, there is, so far as is known, not one survivor. Thousands of them were launched at Pittsburgh and other points in Pennsylvania, while at sleepy old Marietta, there rose a great shipyard from whose stocks came not only flatboats, but keel-boats, arks, barges, and even schooners.

The Flatboats, Other River Craft, and Their Crews

Flatboats, in use as late as 1840, were the ugliest and most ungainly of all river craft. Their average dimensions were sixty feet in length and twenty feet in breadth, and they drew from one to two and a half feet of water. Some were smaller. The flatboat was meant to drift with the current, and was kept in the channel by huge sweeps or oars at the sides or forward, and another at the rear which served as a rude rudder. When two of the sweeps were arranged at the bow and made to stick out from either side, such craft were called "broadhorns," because of the resulting resemblance to the head of an ox. The boats were covered with a heavy roof, which was generally eight feet or so from the bottom, and on it the owners and their families

walked and took the air, as the vessel was borne upon the mud-toned waters. Within was comfort and a more cheerful life than the outside suggested. Forward was a sitting-room, and back of that the kitchen, while down a passageway were several bedrooms. One compartment was for cargo, and back of a bulkhead or heavy partition, were the stables for the animals. When the craft was given up to commercial purposes only, the arrangement of the interior was simpler. Flatboats were often fitted up as floating stores, and were well stocked with groceries, drygoods, and especially Yankee notions. The proprietor standing on the roof or upper deck would blow his tin horn as the emporium neared a landing, and after he had done all the business the spare cash in the town justified, he would cast his establishment adrift and seek other customers down-stream. The flatboat, by the way, was practically a down-stream venture; only when of moderate size could it be moved against the current. This was done by the use of iron-pointed poles, on which the crew bore and prodded with all their might.

Flatboating on the rivers of the Middle West was a calling for men whose blood was as red as their flannel shirts. It took muscle, nerve, and a devil-may-care spirit born of peril and privation. At any turn in the river these men held themselves ready to fight pirates as remorseless as Captain Brand of the *Centipede*, who scoured the Spanish Main, or as cruel as Long John Silver of *Treasure Island* fame. At any moment Indian arrows might sing over the heads, or rifle bullets come whizzing from the low rakish craft hidden in the bushes alongshore. Murder and pillage were the trades of the freebooters who lay in wait for the unwary. At one point in the Ohio on the Illinois bank was a stronghold in the cliffs, known as "the Cave in the Rocks," a den of thugs and thieves, which the river travellers approached with cocked muskets. The gentry who held that evil citadel killed crews, captured the flatboats when they could, and took boats and cargoes to New Orleans and sold them. Many of them were shot, but it was several years before their lair was finally broken up and the band exterminated.

Men fit to cope with robbers are not soft spoken, and the flatboatmen of early river days were hard swearers and easy

drinkers. One of the early American artists, Bingham, who knew the river life well, showed their type in his canvas depicting *The Jolly Flatboatmen*, a roistering group, singing, clog-dancing, and fiddling on the roof of their craft. Generally, however, the flatboaters were a lantern-jawed, ague-faced, slant-eyed lot, who employed their scant leisure in hurling tobacco juice at distant targets with amazing accuracy. Usually they gave themselves up to malarial musings, but when danger and battle came they were galvanized into quick action and rapid profanity. Their lingo was all their own.

"Hell's a-snortin'," roared Red-Whiskered Blake. "Watch us put them galoots out of business quicker nor an alligator can chaw a puppy."

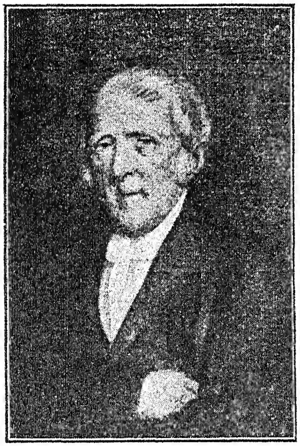
He who was called "The Snag of the Mississippi" and likewise "The Snapping-Turtle of the Ohio," known also as Big Mike Fink, had his last fight long years ago. "I can outrun, outjump, outhop, throw down, outyell, knock down and drag out any man in the country," was his favorite slogan. And it was no idle jest.

Besides the flatboats, there were many other types of craft especially adapted for the peculiar conditions on the Western rivers. Like the flatboats, most of them were planned from forms which had been used on the rivers of the East, especially on the Connecticut and the Delaware.

The keel-boat, as its name suggests, had a heavy timber fastened to the bottom along its entire length, which afforded some protection when the boat struck a snag or a rock. It was propelled up-stream by the use of setting-poles handled by men who walked up and down a narrow running-board built at its sides. When the keel-boat was roofed over it was known as a barge. The Durham boat, so named for its inventor, Robert Durham, who first employed it on the Delaware River, had more graceful lines than most river vessels of the period. It was a keel-boat resembling an Indian canoe. This type was sixty or more feet in length and roomy enough to be available both for freight and passenger traffic. Out of it was evolved the first packets of the Western rivers.

It was a far cry from the dugout to the floating hotels of the palmy days of the Mississippi, but the packet keel-boats which

were soon going out of Cincinnati were, at least, a promise of things to be. They were advertised as comfortable, commodious, and the passengers were assured of "safety." The cabins were recommended as bullet-proof; there were excellent portholes from which to shoot at river pirates, and also a one-pounder cannon. The packet was followed by a convoy in



Courtesy of Stevens Inst. of Technology.

COLONEL JOHN STEVENS. ROBERT L. STEVENS.

Colonel Stevens, born in New York in 1749, invented not only the method of driving ships by screw-propellers, but also the multitubular boiler (1803); established between New York and Hoboken the first steam ferry in the world (1811); and with his son, Robert, made steam navigation a commonplace on the Delaware. He designed the first iron-clad ship (1813), practically an anticipation of the *Monitor*, obtained the first charter for an American railroad, built a steam locomotive with multitubular boiler (1826), and, single-handed, did more for transportation in America than any other man.

Robert L. Stevens, son of Colonel John Stevens, for a quarter of a century stood at the head of the naval engineering profession in this country. The universally prevalent forms of ferry-boat and ferry-slip, the overhanging guards, the fenders, the spring-piling, the ship-walking beam (1821), the split water-wheel (1826), the balance valve for beam engines (1831), the location of steamboat boilers on the wheel-guards are inventions of his.

which were armed men. Such vessels could get to New Orleans in a month, carrying both passengers and cargo.

As the freight business of the rivers began to develop, roofed craft, known as arks, were introduced. They served to transport apples, cider, flour, and later coal, which found a ready sale at New Orleans. When the demand for lumber grew, huge rafts of logs were floated down-stream for European shipment.

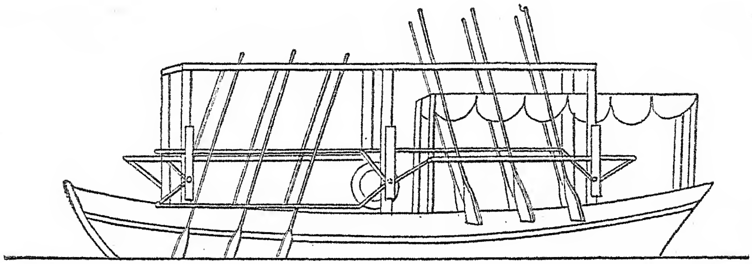
On the Missouri River, more turbulent and more muddy even than its sisters of the valley, craft very much like those seen on the Ohio and Mississippi were put into commission. They were changed somewhat to meet the needs of a navigation in shallower and more uncertain waters. The "bull-boat" was the Missouri's very own, because its principal material, the hide of buffalo bulls, was easily obtained by shooting those now nearly extinct animals ranging the shores of the "Big Muddy." This vessel was made rather round; it was really a big basket, composed of slender saplings and withes. Over the skeleton were stretched the hides, which, as they shrank considerably, made a tight covering. The seams were waterproofed with pitch and gums. The bull-boat was not such a river-worthy craft as the "broadhorn," however, for it was easily punctured by the many obstructions in the channel.

Travelling on all three of these rivers was fraught with peril on account of the many snags, timbers, and jagged rocks, often masked by the shimmering surface. Flatboats, keel-boats, arks were likely to be hung up on a floating tree, or driven high on the numerous islands by capricious eddies. When this happened, the more fortunate vessels in sight went to the rescue, but in most cases, the ill-starred boats proved total losses, and their owners had to make their way back home through the wilderness.

On account of these misadventures and of the great difficulty of working vessels against the swift currents, men invented all sorts of schemes for outwitting the stubborn river-gods. For centuries, horses had been used to provide power for ferry-boats by making them walk a treadmill or an endless-chain arrangement. Horse-boats, a feature of harbor travel in the Eastern waters, brought such cities as New York and Philadelphia in communication with suburbs beyond the rivers. At some points on the Mississippi it was possible to work scows across the stream by means of a small stern wheel, driven by horses. Two adventurers of navigation rigged up an eight-horse team-boat in 1807, and sought to reach Louisville, but they lost control of their vessel at Natchez, where she was so badly damaged that they abandoned her.

Fitch and the Steamboat

The story of the cantankerous streams of the Central States engaged the attention of a Connecticut boy, who did a great deal in later years to conquer them. John Fitch was born in Windsor, Conn., in 1743, and at an early age was apprenticed to a watchmaker. At the outbreak of the Revolution he turned from tinkering escapements to fashioning guns for the army. His interest in the West led him to the Ohio country where he



JOHN FITCH'S STEAMBOAT, EQUIPPED WITH OARS.

became a trader. He and his party were captured by Indians at the mouth of the Muskingum River, and all his goods were destroyed. Fitch was spared, although nine of his companions were killed. As a captive he was made to walk all the way to Lake Erie. He finally made his escape and arrived penniless and worn at Warminster, Pa. There, in 1785, he began work on his steamboat, a device which he had planned especially for conquering the rapid Western rivers. Since 1720, and probably before, inventors had been wrestling with the problem of how to drive boats up-stream by the force of vapor, and at that time experiments were being conducted along that principle in England and France. Fitch probably knew little or nothing about what was being done on the other side of the Atlantic. He believed that the future of the United States depended upon getting the best of the big rivers which were the keys to American inland navigation, and he set his heart upon making this practicable.

As watch and clock maker Fitch had been used to working in brass. Of that alloy he made the model of his first steam-

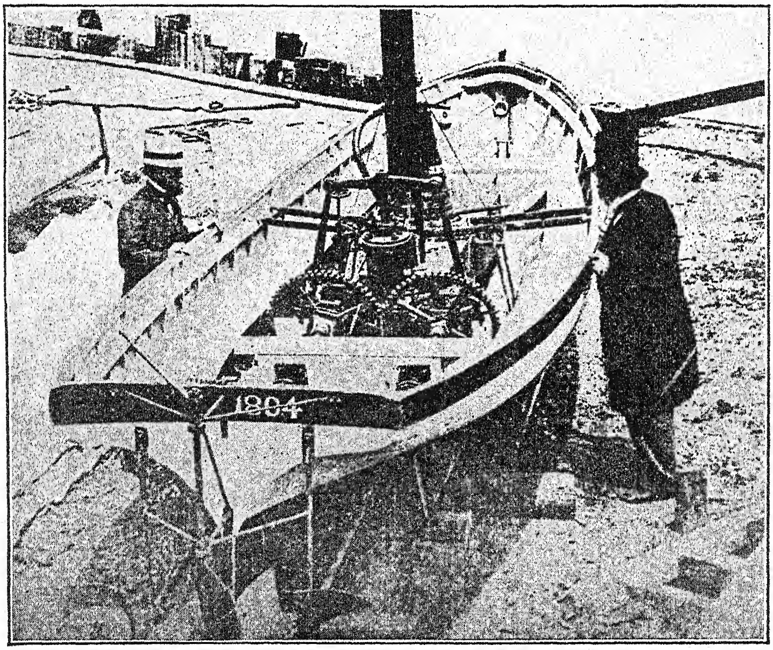
boat which, in April, 1785, he showed to Doctor Ewing, the Provost of the University of Pennsylvania. The educator was much impressed by it, publicly declaring the invention to be a valuable one. That autumn, at Davisville, Pa., Fitch operated his steamboat. It was driven by buckets attached to the sides. The steam-powered machinery set the buckets in motion, and the vessel glided slowly over the water. The inventor made five of his steamboats in all. The buckets did not suit him, and the next model had oars. He finally produced a workable vessel which became a steam ferry-boat, and during the summer of 1790 it plied fairly regularly between Philadelphia and Burlington. In 1796 Fitch demonstrated a steamboat with a screw propeller in the water of Collect Pond in New York city.

Had the general public or the government seen the future of steam navigation at that time, civilization might have set its clock at least twenty-five years ahead in the interior of the United States. John Fitch had the vision, but, like many inventors before and after him, he was alone in his vision. When he once told a group of men of his dream that the Mississippi would be conquered by the power of steam, they heard him forbearingly, and when he left them one of the listeners remarked: "He is crazy, poor fellow!"

The staid old American Philosophical Society, of Philadelphia, consenting to learn from him about the steamboat, apparently saw no possibility of its doing anything very useful. Fitch then took his scheme to Benjamin Franklin and besought his aid. The greatest opportunity which that eminent scientist and statesman ever missed was that of helping the wild-eyed, unkempt, uncouth inventor who poured into his ears a torrent of words about the vessel which was to revolutionize the traffic of a world. Franklin saw only the suffering and distress of the man, and taking him into another room offered him some money, which Fitch indignantly refused.

What hope could there be, thought Fitch, when a savant of international fame, an inventor of distinction himself, could not see that a boat would be driven by steam as easily as it was then moved by the leverage of oars! Without substantial help and encouragement, Fitch went from the government to the legislatures of the various States. Finally, to get rid of him,

he was given the exclusive privilege of navigating vessels by steam in the waters of New York and also those of New Jersey and Virginia. Destitute and despondent, Fitch toiled on in his efforts to get enough capital to build a boat big enough to



Courtesy of Stevens Institute of Technology.

COLONEL JOHN STEVENS'S SCREW-PROPELLED BOAT OF 1804.

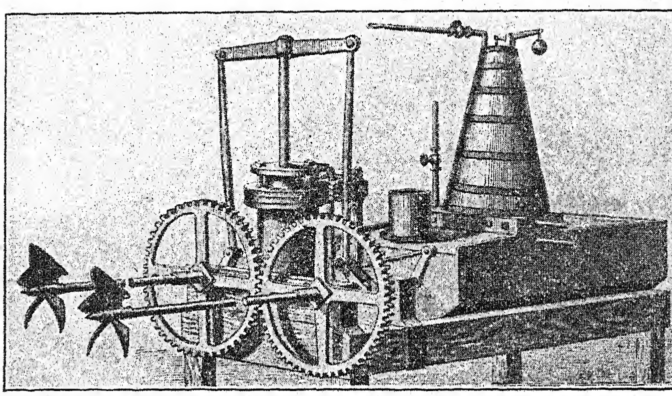
Stevens had seen Fitch's steamboat. He examined the boat and her mechanism, and in 1792, he took out patents for steam propulsion. Nearly a decade before Robert Fulton ran his *Clermont*, Stevens had a steamboat on the Hudson as builder, owner, and captain. Six years later he equipped with double screws this predecessor of Fulton's craft. This is a photograph of a replica of Stevens's screw-propelled boat, taken at the foot of 1st Street, Hoboken, in the sixties.

demonstrate his ideas. Here was his project, given in his own words; and in the light of our present knowledge what can anybody see in it that indicates an unsound mind?

"Where streams constantly tend one way," he wrote, "great advantage will accrue in inland navigation, and particularly in the Mississippi and Ohio Rivers, where the God of Nature knew that the banks could never be traversed by horses and has laid

a store of fuel at their headwaters to last to the latest ages for the very purpose of navigating their waters by fire.

"Here is an estimate which I beg leave to make. It takes thirty men to take a boat of thirty tons burthen from New Orleans to the Illinois. Now, I say, if I could be enabled to complete the experiment, I would obligate myself to make a



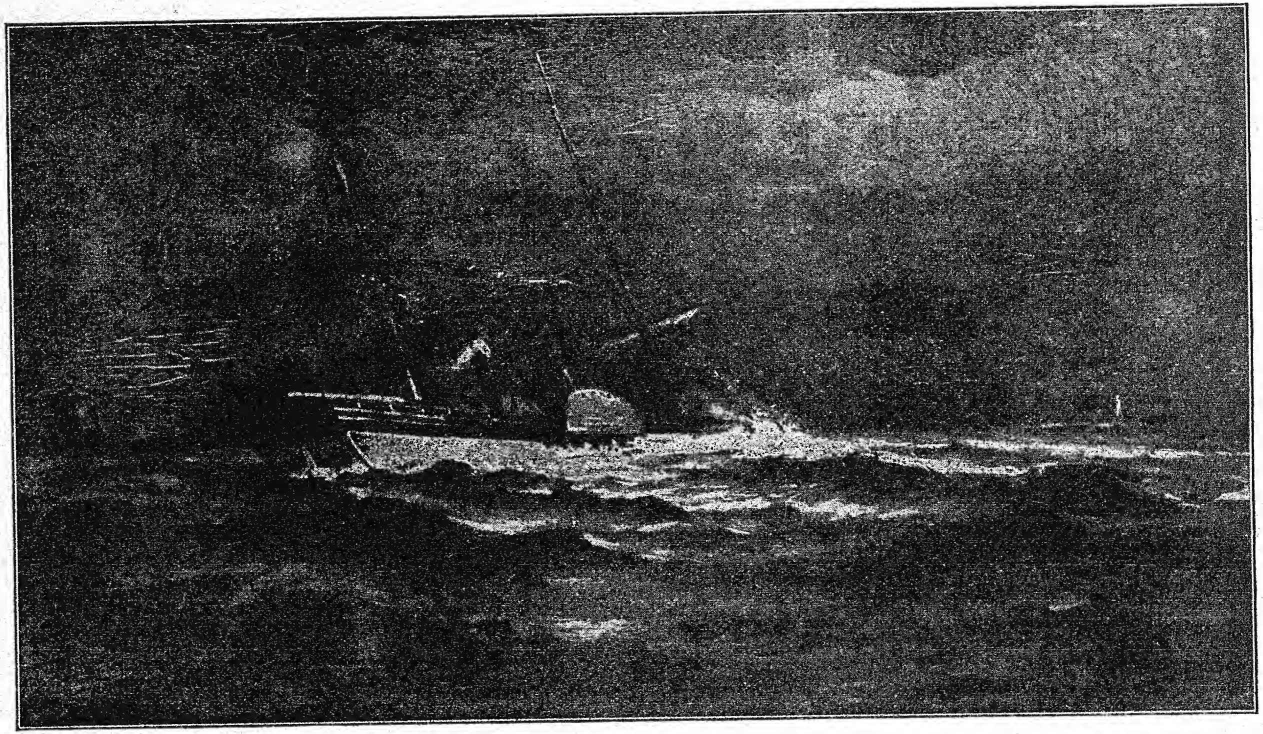
Courtesy of Scientific American.

ENGINES OF STEVENS'S BOAT OF 1804.

Three years before Robert Fulton's *Clermont* ploughed up the Hudson, an engine and boiler, built by Colonel John Stevens, of Hoboken, N. J., had been successfully used in driving a screw-propelled boat. In 1844 this engine, in the presence of a committee, propelled the vessel at the rate of eight miles per hour.

boat of sixty tons burthen which, with engines and all complete, would cost $2000. As that could work double the time of the men at the oars, it could go half the time, and transport 120 tons in the same time that the other would thirty tons. At the rate now charged this would pay for itself and clear $10,000, whilst one boat could make one trip—and larger boats could be made to greater advantage. It would also raise the value of land in the Western territories in proportion."

Failing to get anybody in the United States to see that his invention would benefit the country, Fitch went to France, where he was also unsuccessful. For a time his plans were in the possession of an American consul. They were lent by the consul to Robert Fulton, who was then working on the same problem of steam navigation. Fitch finally retired to his lands at Bardstown, Ky., where he eked out a meagre existence until



Courtesy of Stevens Institute of Technology.

STEVENS'S *PHŒNIX*, THE FIRST OCEAN-GOING STEAMER.

Colonel John Stevens, aided by his son, worked independently of Fulton. Fulton's monopoly of steam navigation on the waters of the Hudson made it necessary for Stevens to employ the *Phœnix* in daring ways. He sent her to Philadelphia from New Jersey by sea. A fierce storm overtook her. After making a safe harbor in Barnegat, she proceeded to Philadelphia and plied many years between that city and Trenton. Stevens thus indisputably earned the credit of first navigating the high seas with a steam-driven vessel.

he ended it by his own hand. His company had failed; "the steamboat" had been junked; and as far as he was concerned "finis" had been written on all his hopes.

Fitch had often stated that some man of wealth would eventually make the art of steam navigation a success and win a fortune. In the very year, 1798, in which the unfortunate inventor ended his unhappy life, Robert R. Livingston, member of an old and aristocratic family and one of the richest men of his time, built a so-called steamboat, with which he failed, however, to make enough speed to maintain a franchise. Chancellor Livingston had taken over the lapsed rights of Fitch, whose boat had not made the required four miles an hour. The boat had been built on the joint account of Livingston, Nicholas J. Roosevelt, and Colonel John Stevens, of Hoboken, all of whom were to become noted factors in the development of power navigation.

Stevens Builds His Steamboats

Colonel John Stevens and his son, Robert Livingston Stevens, receive all too little credit for their remarkable inventions. Stevens had seen John Fitch's steamboat navigating the Delaware River and was much impressed. He examined the boat and her mechanism, and in 1792 he took out his first patent for a method of steam propulsion. By 1798, nearly a decade before Fulton, he was actually navigating the Hudson River with a steamboat of his own. In 1804, he built a revolutionary type of craft—a screw-propelled vessel, the first of its type. He was probably the best engineer of his time in America. Stevens, in 1807, built his side-wheel *Phœnix*. Prevented by the monopoly granted to Fulton and Livingston from navigating the Hudson River, he boldly sent the *Phœnix*, in command of his son, to Philadelphia, in 1808. Although the vessel had to put into Barnegat because of a violent storm, she was undoubtedly the first steam-driven craft to navigate the high seas. For six years she plied between Philadelphia and Trenton.

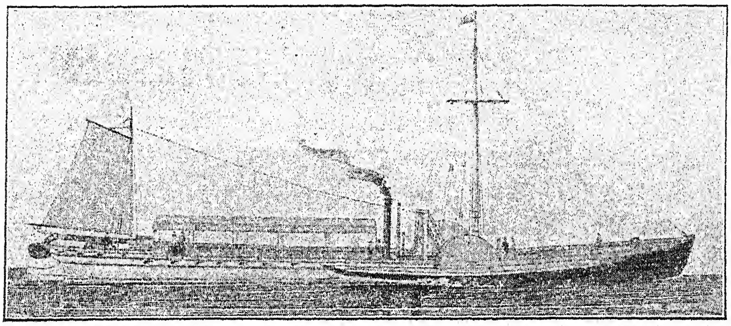
In the construction of the *Phœnix* Stevens, then over seventy years of age, was assisted by his son Robert, who became the foremost marine and railroad engineer in the United States. The railway exploits of Robert are recounted in the chapter

"From Stephenson to the Twentieth Century Limited." The utmost speed that Fulton thought possible for a steam-driven boat to attain was seven miles an hour, and this he accomplished in his later vessels. It was reserved for Robert L. Stevens, after long and cautiously conducted experiments as to the form of vessel best calculated to overcome the resistance of water, to design and build a boat which made what seemed then the dizzy speed of thirteen and one-half miles an hour. With his *New Philadelphia*, there began the first day line to Albany. Robert Livingston Stevens gave the modern American ferry-boat and river steamer their familiar forms. He was the first to invent, in 1818, the method of using steam expansively on shipboard, and he devised the now prevalent form of ferry-boat, ferry-slip fenders, and spring piling. The walking beam, too, was first applied to shipping engines by him in 1821. The enumeration of his many useful inventions would fill several pages.

Fulton and Livingston

Chancellor Livingston went to France as the United States minister, and in Paris he came in contact with Robert Fulton, who was then busy with the invention of submarines and torpedoes. He had given some attention to American navigation, as he was an advocate both of the steamboat and a canal system. When only thirteen, Fulton's dream of conquering the waters with a force stronger than that of poles or oars began to be realized, for at that age he constructed a boat which he moved with side paddle-wheels. His painting of miniatures had gained for him the friendly interest of Benjamin West, the Philadelphia artist, with whom he lived for several years in London. While Fulton was conducting experiments on the Seine, he formed a lasting friendship with Livingston, out of which came the revival of the steamship project. He studied what English and French engineers had done on the subject, then returned to the United States, intent on bringing his experiments to a successful issue. As Fulton himself often said, he never claimed the idea of the steamboat as his own, but only the ability to make a steam-driven vessel which could be operated with practical success.

Before he left Europe he had shipped to New York a good steam-engine from the famous works of Boulton and Watt, at Soho. On his arrival in America he began the construction of the wooden hull of the steamboat, later named the *Clermont* in honor of the Livingston's country-seat up the Hudson River. A memorable year was 1807, in which *Fulton's Folly*, as the scoffers had called the *Clermont*, ended her trip from New York city, up the Hudson, to Albany. She had made the run of 150 miles

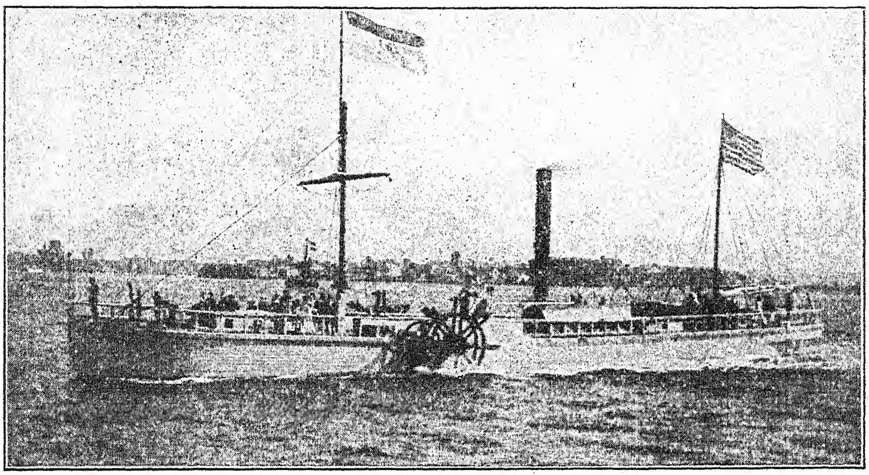


ROBERT FULTON'S STEAMBOAT, THE *CLERMONT*, 1807.

in thirty-two hours, which gave her a speed of nearly five miles an hour and a good margin over the four miles required in order to maintain an exclusive grant for steam navigation in the waters of the Empire State. There was a stop overnight at Clermont, the chancellor's estate, where congratulations were showered upon the promoters. Thus, for the first time on any river, was steam navigation on a large scale made a commercial success.

Livingston and Fulton lost no time in following up their advantage. The *Clermont* was lengthened and broadened, her machinery made more efficient, and passengers made more comfortable by the building of the paddle-wheels outboard, so that these contrivances hung over the water. The passengers were also enclosed, an arrangement which saved them from being doused at unexpected times. Then came the launching of two other steam craft, the *Paragon* and the *Car of Neptune*, closely followed by that forerunner of lake and river hotel-steamboats and the costly ocean steamships which cross the

Atlantic in a week. This was the *Savannah*, the first steam vessel to cross the ocean to England, which trip she made in the year 1819. She was named from the city in which she was largely owned, and sailed under the American flag. The engines of the *Savannah* were constructed in the old Speedwell Iron Works in Morristown, N. J., where Samuel F. B. Morse



REPLICA OF FULTON'S *CLERMONT*.
The reconstructed *Clermont* took part in the Hudson-Fulton celebration.

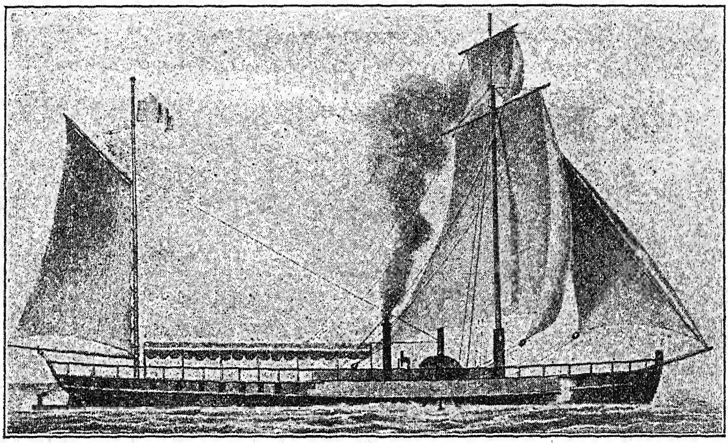
worked out his invention of the submarine telegraph. Thus in a little factory in the New World were brought into being two means of uniting continents and defying space and time. The *Savannah*, however, was really only an auxiliary steam-craft, as her paddle-wheels were often removed on her voyage when the weather was rough. But she had shown the way to the shipbuilders of Europe, and British inventors and builders soon developed the ocean steamship, and made good once more the boast that Britannia ruled the waves.

In America, as a result of the prevailing policy of granting broad, exclusive franchises, the promoters of the steamboat were able long to enforce their exclusive control, and to make giant strides in inland steam navigation. Malice and jealousy could not stay that wonderful progress. In vain did the captains of sloops and schooners of the Hudson seek to injure the new

steamboats by running into them. More drastic laws were passed to punish such malicious mischief. The old sailing masters eventually bowed to the inevitable, and some of them joined the crews of steam-driven vessels.

Developing the Water Navigation of the West

None read the doom of sail more quickly than did a steel-thewed youth who stood at the tiller of a sloop which plied as



From Valentine's Manual of 1852.

FULTON'S *PARAGON.*

After the success achieved with the *Clermont*, Fulton and Livingston built the *Paragon*.

a ferry between Staten Island and the Battery of New York city. A commander on his own deck at sixteen, this son of a New Dorp farmer had the genius of the Dutch for seamanship and the readiness of the American to grasp opportunities. Cornelius Vanderbilt, growing to man's estate, won a fortune and fought the first American steamboat trust to a standstill. With Daniel Webster as his counsel, he attacked the syndicate of Livingston and Fulton in the Supreme Court and defeated it on the broad grounds that any control over waterways by private interests was a violation of the Constitution of the United States. A mighty decision it was, for it established, for all time, the federal responsibility for navigable rivers and harbors, and started this country on that great enterprise which

resulted in the deepening of channels and the fostering of both ocean and inland navigation.

Commodore Vanderbilt, with a title won through his becoming the owner of a steamboat line, flung his restless energy into the fight for the Hudson and out of that came the splendid transportation lines of the American Rhine. When the rivalry was at white heat passengers were carried from New York to Albany for a dollar each, and finally for ten cents. They had to pay, of course, for their meals and staterooms, but the accommodations they got were the last words in luxury. The controversy, as it flamed high, advertised far and wide the beauties of the majestic river, and hundreds of thousands of persons both from these and foreign shores felt that they had missed much in life until they had made at least one trip upon the famous Hudson River.

Another of that doughty Dutch race, one closely connected with Theodore Roosevelt in blood, was Nicholas J. Roosevelt, pioneer for the steamboat on the turbid waters of the Middle West. Like Fulton Roosevelt had dreamed when a boy of an age of power on lake and stream. Nicholas Roosevelt was born in New York city, in 1767. Until he grew to manhood he spent his days on the country estate of his family near Esopus, New York, where he was living when the British forces were holding the island of Manhattan. His boyish activities often took him to the neighboring Hudson, and among his recreations was the running of a little power craft of his own invention. This boat was an embryo *Clermont*, for it was moved by paddle-wheels at the side. The motive force came from the action of whalebone and hickory springs imparted by a cord to the axle, on which were the wheels. Although Fulton had also employed paddle-wheels in his youthful experiments, he was at first inclined to use floats and chains for the *Clermont*, and was only dissuaded from doing so by Chancellor Livingston and Roosevelt. Indeed, it has often been asserted that Roosevelt was well justified in his claim for a patent on the steamboat paddle-wheels and boxes.

On account of his previous association with Livingston, Nicholas Roosevelt became enthused with the idea of advertising the advantages of steam, and he started out at once to con-

vert the West. With authority from the Livingston-Fulton combination, he started on his promotion tour. He found so many sceptics that he fortified himself against objections to the new power by observing conditions at first hand in a flatboat trip down the Ohio. Convinced that his idea was feasible, he caused coal-mines to be opened at certain landings, so that there would be no lack of fuel for the steamboat which he knew would soon be picking its way among the islands of the Ohio. On the strength of his own survey, Roosevelt was authorized by his backers to spend $38,000 for the building of the hull of a river steamboat, for which most of the machinery was shipped from the East.

The Days of the Mississippi Steamboat

"Even a raft can float down-stream," chided the critics, when they saw the *New Orleans* making for Louisville. "Just wait till the old tea-kettle tries to go up-stream."

She did go up, with hum and whistle and with her decks crowded with Rooseveltian converts. The age of the river steamboat had come; a gilded age tinged with romance to this day. From the launching of the *New Orleans*, in 1811, and the *Vesuvius*, for the lower Mississippi, in 1814, the rivers took on a new life. But it became evident that the old stream, which tore out its banks and cavorted in a way which would have scandalized the placid, classic Hudson, must have a steam-craft especially designed for it. This want was partly met by Henry Shreve, a young man who modelled a double-decked steamboat of shallow draft, whose engines were on the main deck instead of being buried in the hold. He was arrested and prosecuted, and came near serving a long term in jail for his infringements, but the *Washington*, which he planned, came up to all the requirements.

With the breaking up of the Livingston-Fulton monopoly in 1824, the rich and colorful life of the Mississippi under steam burst forth with all its glamour and glory. It drew to it the young and the adventurous from all the surrounding States, and even from the Atlantic seaboard. The riotous Missouri caught the fever, and soon steamboats of even lighter draft were in commission on the bosom of the Big Muddy. The smoke from the

stacks of these devil-boats of the white men made the Indians rub their eyes. Among those who caught the lure was a boy at Hannibal, Mo., who went as a lad to learn to be a pilot and became a master of literature under his pen-name of Mark Twain. The strange pseudonym came from the cry of the leadsman, and meant that the water he was sounding was at the two-fathom mark.

On the rivers of the big central valley, the flatboats and the scows long held their own, and indeed rafts were often sighted on the way to the Gulf. But before long the roustabouts of the flatboats became the deck-hands of the steamboats. With the growth of steam navigation the government provided power snag-boats and dredges operated by steam to clear the channels of obstructions. Travelling was somewhat safer then, and big barges, large floating stores, floating theatres, and a circus amphitheatre were added to the stream of traffic, for they could all be towed by steam-tugs. The troublesome Mississippi was never thoroughly tamed, however, and even though huge embankments and levees were built to stay its sudden floods, it still wandered a mile or so from its bed overnight, leaving steamboats stranded high and dry.

As the steamboats increased in size and power, competition among their owners manifested itself in open rivalry. High-pressure boilers were introduced and the whistles shrieked the challenge of the race by day and night. The captains of the white-hulled craft, regardless of the twisting channels and the risk of snags, hurled defiance and vibrant oaths at all comers. They risked life and property without a qualm. If coal and wood gave out, goods, lard, bacon, hams, tar would do just as well for the hungry, fiery maws of the furnaces. The scalded stokers, naked to the waist, yelled and cursed, as with "a nigger squat on the safety-valve" the trembling wooden vessels careened down-stream in belching clouds of smoke. Fires and explosions were frequent, and there was more than one Jim Bludso who stood at his post in the pilot-house and held the nose of the boat against the bank until every passenger was ashore. To the timid, the sign "Low Pressure," painted on a paddle-box, was reassuring.

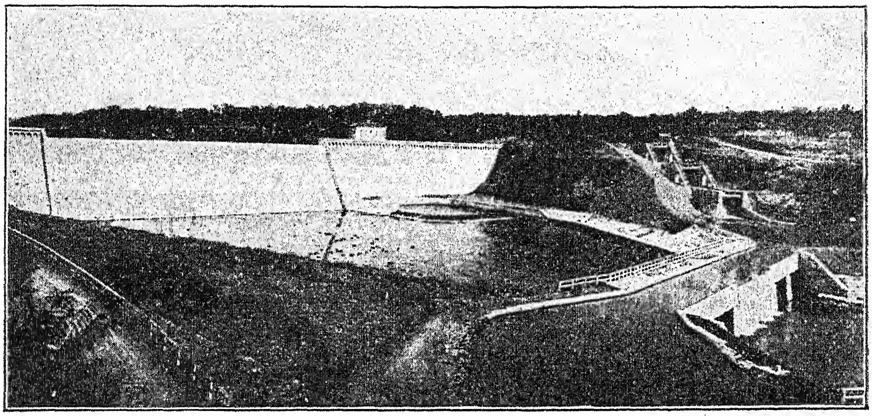
The days of the *Sultana* and the *Southern Belle* have gone

into the limbo of things that were; but there are still old stern-wheelers on the Mississippi with the old thrill along their keels. Once in a while, as old race-horses are wont to do, they try each other's speed for a mile or two. With the coming of the railroad and the canal the pulse of the traffic in the Mississippi slowed down. The steamboats of the old type suffered by comparison with the railroad largely because they carried so many deck-hands, and with the demand for higher wages they were no longer profitable. There was no more picturesque sight in the old days than the antics of the roustabouts who took freight in at the landings and hustled what cargo was waiting on board. They had periods of leisure, however, which piled up heavy overhead charges which could hardly be met under new conditions. Still, with the introduction of cheaply operated barges burning oil, a profitable freight business is again being built up in the valley, and it is growing apparent that the railroad cannot do everything.

The Great Lakes and the Canals

An entirely different system of inland transportation is that which is built about the Great Lakes and the canals. There were very short canals in the United States long before the successful outcome of the American Revolution, but the history of these artificial channels is bound up in the navigation and use of the 80,000 square miles of those land-locked seas separating part of the United States from Canada. Even early French explorers had long recognized the value of the Great Lakes, but it remained for the canal-builder to make them useful to industry and commerce. One of the results of General Washington's trip into the Western wilderness, after independence had been won, was his plan for connecting the Atlantic seaboard with the central rivers. He had also approved the project of joining the waters of the Hudson with Lake Erie by canal. As president of the Potomac Canal Company, founded for the purpose of digging the connecting channel from Chesapeake Bay to the Ohio River, he did not live to see the fruition of his plans. He was able, however, before his death, to support in every way the view of Gouverneur Morris, the eminent financier, that the day was much to be desired when "the waters of

the great inland seas would with the aid of man break all their barriers and unite with those of the Hudson." Such a plan was urged again, in 1808, by Albert Gallatin, the secretary of the treasury; but it was not until 1817, ten years after the first commercially successful steamboat had been launched, that this mighty project was under way. In those days there were no



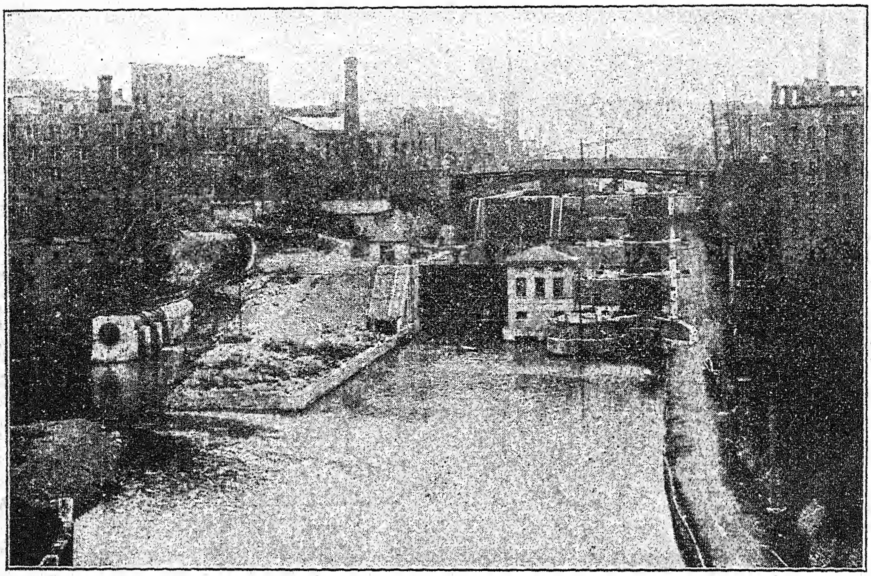
Courtesy New York State Barge Canal Commission.

DAM AT DELTA RESERVOIR, NEW YORK.

This reservoir, five miles north of Rome, impounds the flow of the Mohawk near its headwaters. Water from the Delta Reservoir passes down the Mohawk and enters the canal at Rome. The Delta Reservoir has a surface area of four and one-third square miles. The canal seen in the view is the Black River Canal.

excavation engineers, no contractors on a big scale, and the day of power machinery and steam dredges and shovels had not dawned. American zeal, however, began the task of felling primeval forests, pulling up enormous roots, and removing millions of tons of earth, which work was carried on for eight years before "Clinton's Ditch" was done. A proud day it was for DeWitt Clinton, governor of the Empire State of New York, chief advocate of the canal, when from a ceremonial barge he emptied two kegs of water from Lake Erie into the waters of the Hudson and proclaimed the marriage of ocean and inland sea. When this great artificial channel was opened in 1825, the commerce of the Great Lakes, long pent up and undeveloped, began to pour toward the ocean ferries. The wheat and wool of Ohio, the coal of Pennsylvania, and the copper of Lake

Superior, were thus to find their way to the waiting ships of foreign lands. Along the route of the Erie Canal sprang up thriving communities. Buffalo which had been hardly more than a trading-post, became a busy city. In the municipality of New York, 3,500 new houses were built in the year the arti-



LOCKS AT LOCKPORT, N. Y.

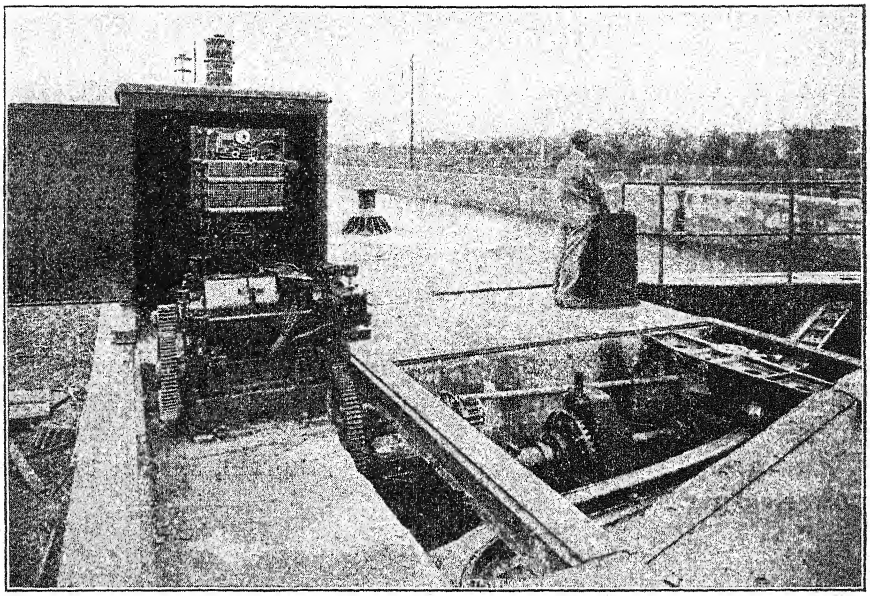
Two locks of barge-canal dimensions have supplanted a tier of five old locks. Another tier of locks has been retained. The two locks have a combined lift of forty-nine feet.

ficial strait was opened, and it soon boasted a greater export trade than either of its ancient rivals, Boston and Philadelphia.

Then came an era of canal-building which developed almost side by side with the spread of steam navigation, although the canal did not call on mechanical power for many a year to propel its craft. Philadelphia hastened the completion of the long-delayed Union Canal. The Western States speeded their canal-digging programmes at every point. Ohio, alert to get all the trade she could both from the North and the South, connected her great river of the lower boundary with Lake Erie, coming in touch not only with the many ports of the inland seas but also finding a way to reach the Atlantic seaboard with

heavy freight. Numerous other canals were excavated in response to the demand for a network of communication throughout the nation.

Although the day of the railroad was drawing near and steamboats had become an accepted means of travel, the public



Courtesy of the General Electric Company.

OPERATING A GATE ON THE NEW YORK STATE BARGE-CANAL.

quite unexpectedly developed a wish to be canal-boat passengers. As the boats were intended primarily for freight, their owners had to change their plans to meet the demand. The canal-boats, which are really modified keel-boats or barges, were quickly fitted with cabins, and the travelling public welcomed. Thousands of immigrants chose this method of transit on their Westward journey. For business men, who wanted to proceed to their destination with all speed, express canal-boats were devised. They had finer accommodations than the so-called line boats, and were drawn by speedier horses or mules. Passengers of social pretensions, dressed in fashionable attire, could sun themselves on the roof, provided—especially if they wore silk hats—they ducked their heads when the crew sounded the

warning, "Low Bridge." The voyagers slept in bunks along the sides of the cabins, which also served as dining-saloons when the bunks were folded up after the manner of the berths in modern Pullman coaches. The freight and passenger business of the Erie Canal and that of the Ohio canals grew to enormous proportions before the opposition and competition of the railroads caused many of the familiar channels to be abandoned. The canals of the United States, however, were not so easily to be put out of the running. Some of the more elaborate ones, such as the venerable Morris Canal in New Jersey, which has few locks and depends upon inclined railroads or planes to lift its boats from one level to another, remain as picturesque relics.

While some wiseacres were singing the lay of the last canal, conditions were arising in the Great Lakes and elsewhere which called for a new policy toward the artificial waterways of the country. Navigation on the huge area of the bodies of fresh water had developed in an amazing manner. From the introduction of the steamboat, and with the launching of the old *Walk-in-the-Water* at the Lake port of Buffalo, special types of power-craft were introduced.

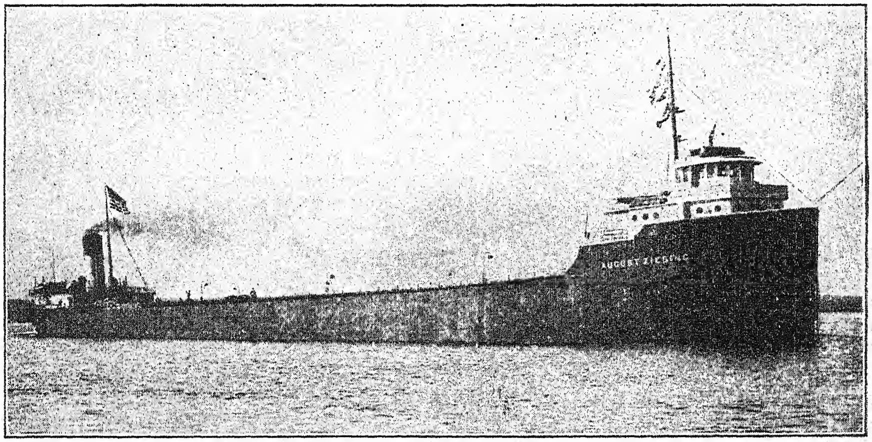
The Age of Steamboats

The age of steam came to the Great Lakes at about the same time it dawned upon the big rivers. The first steamboat to dip into the unsalted seas was the *Ontario*, which was launched at Sacketts Harbor under a grant from the heirs of Robert Fulton. A heavy swell and choppy waves at this particular point often made navigation difficult. The *Ontario* got out of control at first, and wrecked her pier in trying to get back. The first steamer on Lake Erie, the *Walk-in-the-Water*, was better adapted to the disposition of the inland waters and did far better than the *Ontario*.

The services of hardy Lake sailors, men of the stamp who made possible the victory of Commodore Perry on Lake Erie, were enlisted to man the new Lake steamboats. The discovery of copper and of rich iron deposits on the shores of Lake Superior, the demand for bottoms to bring the wheat of the great Northwest into Chicago or to the Erie Canal, stimulated traffic

to a high degree. As there was no heavy foreign competition, the shipping on the Great Lakes soon grew to be considerably more than half that of the entire nation, and gave to our inland navigation larger vessels than those maintained on the interior waters of any other country.

The passenger and pleasure traffic of the Lakes is carried on enormous excursion steamers which are as well appointed as



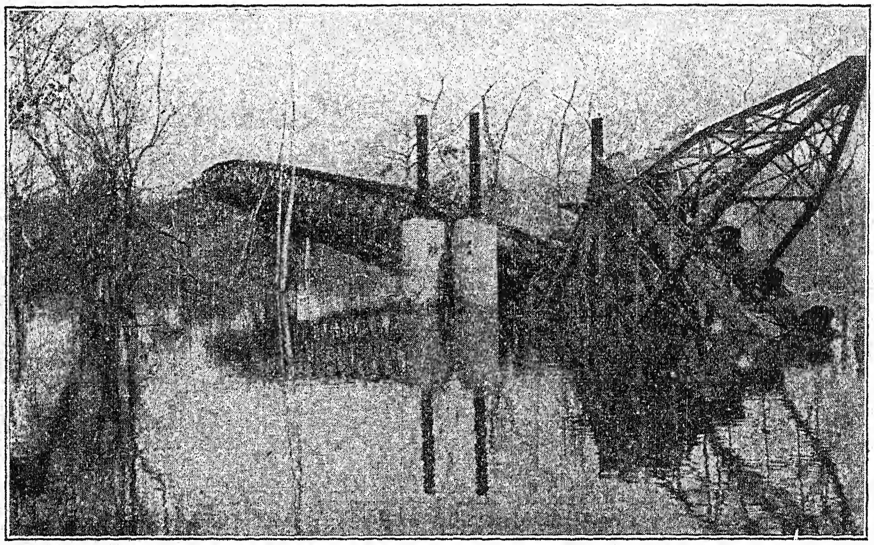
AN ORE-CARRIER OF THE GREAT LAKES.

This type of vessel was especially developed for the rapid loading and unloading of ore.

the finest ocean liners. The freight is handled in vessels which are peculiarly adapted to Lake conditions. The whaleback (now almost obsolete), a cigar-shaped craft the hull of which was covered with curved plates of steel—the invention of a Scotchman, Captain McDougall—was especially adapted to Lake traffic. Laden with iron ore and copper, the improved successors of the "whalebacks" make quick trips in the Lakes, and as they are speedily loaded and unloaded with devices which permit the handling of a whole train-load in a few hours, they are increasing in favor with inland navigators. Ore is literally poured into them, settling down into their holds by force of gravity; and when the vessel reaches its destination automatic grab-buckets as quickly remove it. Large quantities of grain are handled in much the same way.

Although navigation on the Great Lakes is closed in winter, it makes up in summer for lost time. During the season thousands of salt-water sailors join the hardy mariners of the Middle West in manning the huge fleets carrying raw material for American furnaces and mills.

The usefulness of the 90,000 square miles of the land-locked seas is increased by canals. Between Lake Superior and Lake

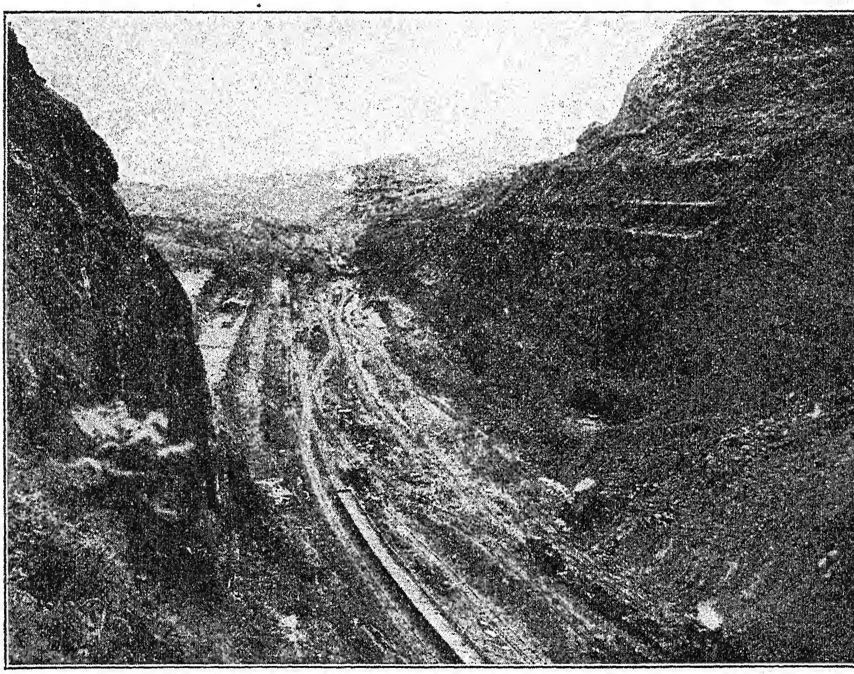


Courtesy of the Panama Canal Commission.

MACHINERY ABANDONED BY THE FRENCH AT PANAMA.

Huron is an artificial channel, making up for the shallowness of the natural outlet, the St. Mary's River, in which there is also a waterfall. Through this ship-canal, twenty feet in depth, millions of tons of heavy freight pass every year. Between Lakes Erie and Ontario there is the Welland Canal, which was begun by the Canadian Government in 1824, about the time the Erie was nearing completion, and opened, in 1832, to connect the Great Lakes more closely with the St. Lawrence. This channel is fourteen feet in depth, and through it pass vessels of larger register from the inland seas to the Atlantic. The difference in level between the two lakes, taken care of by locks, amounts to 300 feet.

Although there are many abandoned canals, once busy channels of trade, the commerce of the Great Lakes has done much to keep in commission numerous straits dug to supplement the rivers. There was a time when even the Erie was reaching its last stages, but the indomitable energy of Theo-



Courtesy of the Panama Canal Commission.

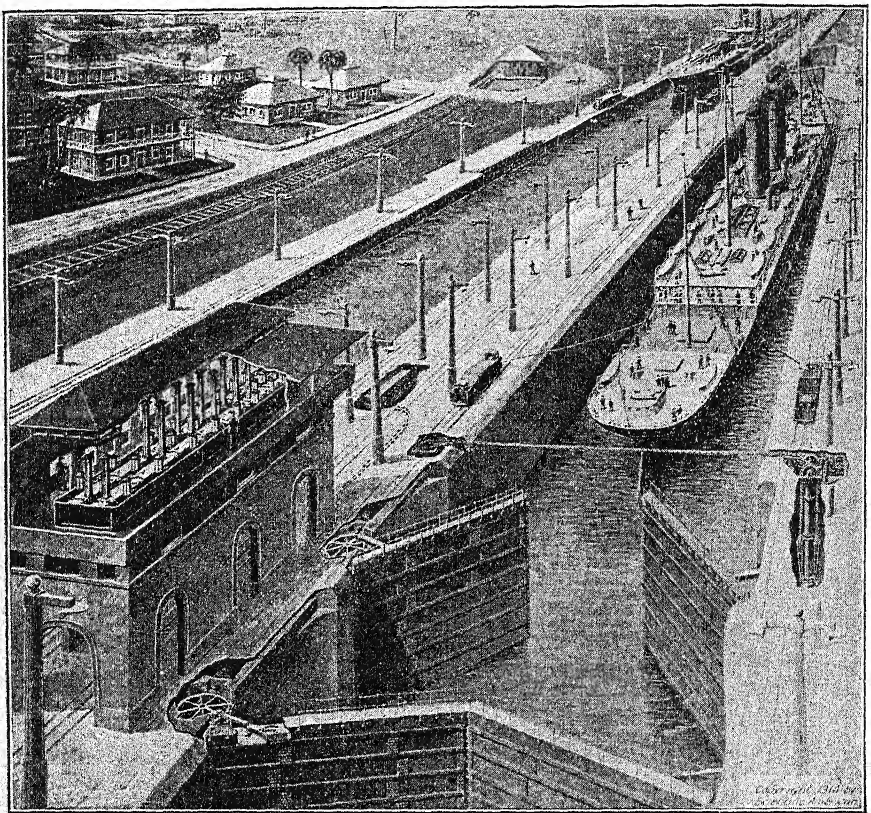
CULEBRA CUT, CULEBRA.

Deepest excavated portion of Panama Canal, showing Gold Hill on right and Contractor's Hill on left. June, 1913.

dore Roosevelt brought a canal revival to the nation. When he was governor of New York State he became so deeply interested in inland navigation that he started the movement which resulted in the expenditure of $100,000,000 in the broadening and deepening of the old Erie into a modern barge-canal. By canalizing rivers and much dredging, this great liquid highway across the Empire State has received a new lease of life.

The revised Erie differs in construction from the old in that it makes use of slack-water navigation. There are 446 miles of

the barge-canals, the Erie being 339 miles in length. The size of the channels varies according to locality, the minimum depth being 12 feet. The main line is 125 feet in width where it is cut through the earth sections; 94 feet where the course has



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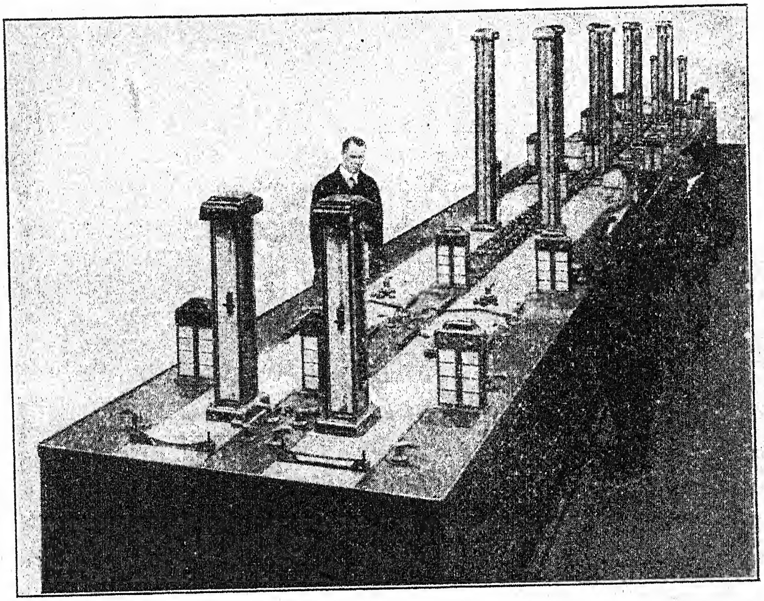
HOW SHIPS ARE ELECTRICALLY CONTROLLED IN THE PANAMA CANAL.

The passage of a vessel through the locks of the Panama Canal is controlled by means of a remarkable switchboard located in the building at the left. A detailed view of the switchboard appears on page 101. Every stage of the passage—the rise and fall of water in the locks, the opening and closing of gates—is indicated by electric lights.

been blasted through the rock, and 200 feet in width in the channels marked by buoys. Fifty-seven locks regulate the flow of the water at the changing levels.

In the early canals, locks were ponderous gates of wood,

opened and closed only with great labor. The barge-canal has locks of reinforced concrete equipped with massive doors of steel which are made to swing by electricity on metal pivots, and they can be opened and shut within half a minute. The machinery of the barge-canal alone cost the State of New York about $10,000,000.



Courtesy of the General Electric Company.

THE MIRAFLORES LOCK CONTROL BOARD, PANAMA CANAL.

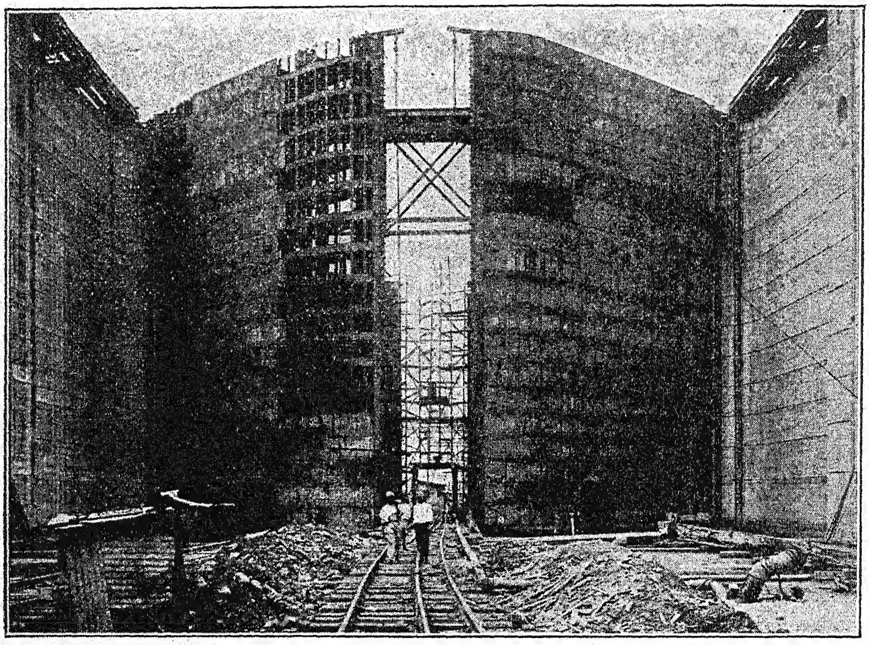
The course of a vessel through the locks of the Panama Canal is controlled by electric switchboards. The men at the switchboards need not see the vessel. The height of the water in the locks, the opening and closing of the gates, the positions of the moving parts of a lock are all electrically indicated, chiefly by lights on the switchboards.

With the coming of the new method of construction the old tow-path, over which the hauling mules were driven, passed into history. Now the barges are either self-propelled by electric power or towed by tugs.

Another interesting new canal development is the sluice cut through the neck of Cape Cod, thus furnishing a safe and easy passage for craft which before had to chance the rigors of an outside route.

The Panama Canal

Of especial importance, both for peace and war, is that combination of canals and rivers—found in the eastern and southern United States—which permits the passage of vessels of light draft, such as torpedo-boat destroyers, without their having to navigate the ocean. On such waterways as these, swift motor-boats are important factors in the development of communication. It would be an ideal state of things, if the American continent were spanned from the Atlantic to the



Courtesy of the Panama Canal Commission.

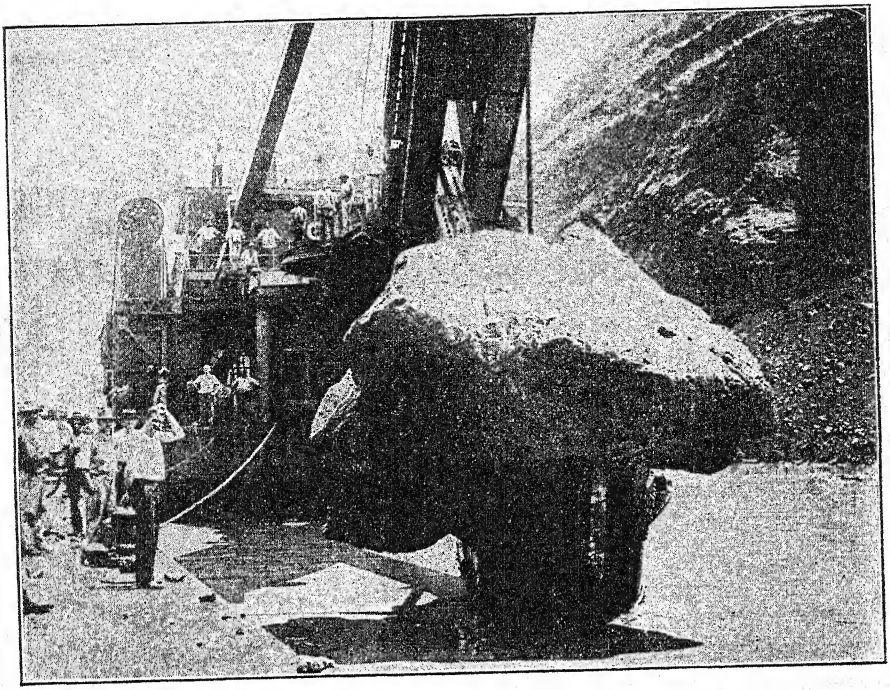
CONSTRUCTION OF GATUN LOCKS, PANAMA CANAL, SHOWING THE HUGE GATES.

Pacific by a huge lagoon, but owing to the enormous differences in level, especially in the mountainous West, this dream of transportation could hardly be realized.

Theodore Roosevelt, leader of the proponents of the inland waterways, when he became President of the United States, gave himself over, heart and soul, to the great project of cutting in twain the Isthmus of Panama, which joined the two Americas.

The digging of this big ditch brought the extreme West and the East close together, and proved an important factor in the development of international commerce.

The mighty plan of cutting down the distance between the two coasts and saving the tedious and hazardous trip around



Courtesy of the Bucyrus Company.

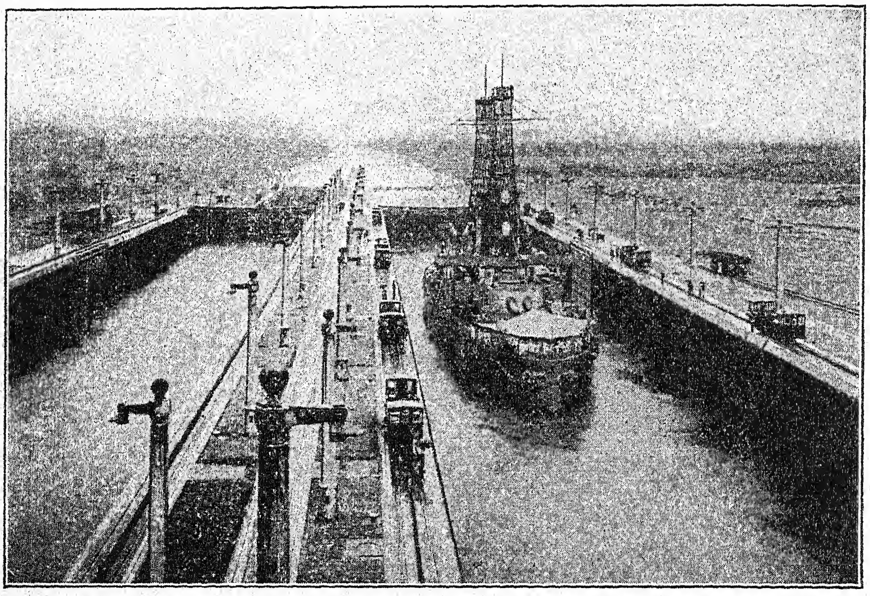
STEAM DIPPER AT WORK IN PANAMA CANAL.

This boulder weighs over fifty tons and was blasted three times while it was resting on the dipper before it could be deposited in the removing scow. At times more than thirty boulders were blasted in this manner in a day.

stormy Cape Horn was conceived shortly after the discovery of America, although many centuries passed before the vision of the Spanish conquistadores was translated into terms of dredges and steam-shovels. A French company, of which Count Ferdinand de Lesseps was the directing genius, began the digging of a canal in 1880, but after millions and millions of francs had been spent the work was suspended; costly machinery, assembled at a great cost, fell into decay and rusted under the tropic skies.

The United States acquired the title to the abandoned route and, in 1904, began the colossal task of finishing the work. Ten years and three months later the Panama Canal was opened to the fleets of the world.

The Canal traverses a zone, obtained by special treaty on the payment of the sum of $10,000,000. The acquisition of the



Courtesy of the General Electric Company.

U. S. S. *WISCONSIN* IN MIDDLE EAST CHAMBER OF GATUN LOCK, PANAMA CANAL.

Electric locomotives haul the ships through the locks.

needed territory was pushed through by Theodore Roosevelt, in accordance with the quick initiative which the Roosevelts have always shown; he had made up his mind that the Canal had to be built—and it was.

This great waterway is 50 miles in length; has a minimum width of 300 feet and a minimum depth of 41 feet. It cost $375,000,000, including the $40,000,000 paid to France for the old route. When the work was at its height a veritable army of 44,000 laborers were employed, and in all 238,000,000 cubic yards of earth and rock were excavated. The "spoil," as taken

from the big prism, would build sixty-three pyramids the size of Cheops. It could have been piled into a structure of the bulk of China's Great Wall, which would easily have stretched across the continent, or almost as far as the distance between New York and San Francisco. Some of the débris was employed as a core or filling for the great Gatun Dam, which was built to impound the waters of the fretful Chagres. The dam itself is a mile and a half long, and half a mile wide at its base, and tapers up to 400 feet in thickness at its top.

Mountains of cement were needed to construct the works and locks about the big Canal, so that ocean liners might pass from ocean to ocean as quickly as though they were small barges going through an Ohio creek. On the whole, the transfers from one level to another are made even more rapidly than was possible in the early days of canal-boating on this continent. The locks of Panama are 1,000 feet in length, 110 feet in width, and have a depth of 41.66 feet. The gates of steel are seven feet thick, and they weigh from 450 to 700 tons each, according to their width and height. The many millions of gallons of water which are poured in and out of these locks are forced through valves and culverts. Where vessels are unable to use their own power the government provides towing locomotives, driven by electricity, which run along the tops of the locks, four in tandem, and in a very few minutes speed even heavy war ships on their way.

Considered as a means of aiding the internal commerce of the United States, the Canal can cut off the steaming or sailing distance of any vessel bound from New York to a port on the Pacific coast by 8,415 miles. Eventually, it will be of still more value in developing our trade with the Central and South American republics.

Our inland navigation bears a very close relation at all points to foreign trade, for many of the cargoes are brought from the inner regions for transfer direct to vessels loading for Europe.

CHAPTER III

ELECTRIC CARS AND TRAINS

TEARFULLY but bravely the young wife handed to her boyish inventive husband, "Tom," the silk dress in which she had been married only eight years before. He needed it in his work as an inventor. It had been carefully folded away in lavender by the beautiful bride when, in 1827, Thomas Davenport, the active but studious village blacksmith of Brandon, Vt., had so far forgotten his profound interest in the "galvanic magnet" of Joseph Henry as to fall in love and "settle down." Only a few miles away, Professor Henry was making at the Albany Academy his immortal discoveries in electromagnetic induction and the principles of the telegraph; and one or two of his novel magnets had been taken to the Penfield Iron Works, near historic Ticonderoga, for sifting magnetic ore. Rumor in those rural districts even had it that such a magnet could hold up an anvil, like Mahomet's coffin, 'twixt heaven and earth; and dreaming Tom Davenport felt he must see it and get one. But trade at the Brandon forge was brisk, a little family began to grow up around it, and even a brick home was built. Going across Lake Champlain to Penfield one day in 1833 to get iron needed in the shop—it could have been got nearer his village—poor Davenport yielded again to the charm of those wonderful magnets. Their spell was so strong that he took the pitiful little eighteen dollars he had brought, and carried back, instead of iron, an electromagnet and some batteries to excite it. How much more he needed that cheap little equipment! Impatient customers with broken buggies and lame horses might wait angrily around his door, while he, forgetting the smithy, handled the mysterious magnet reverently, a humble worshipper at the shrine of Nature's secret. "Like a flash," he says, "the thought occurred to me that here was an available power which was within the reach of man."

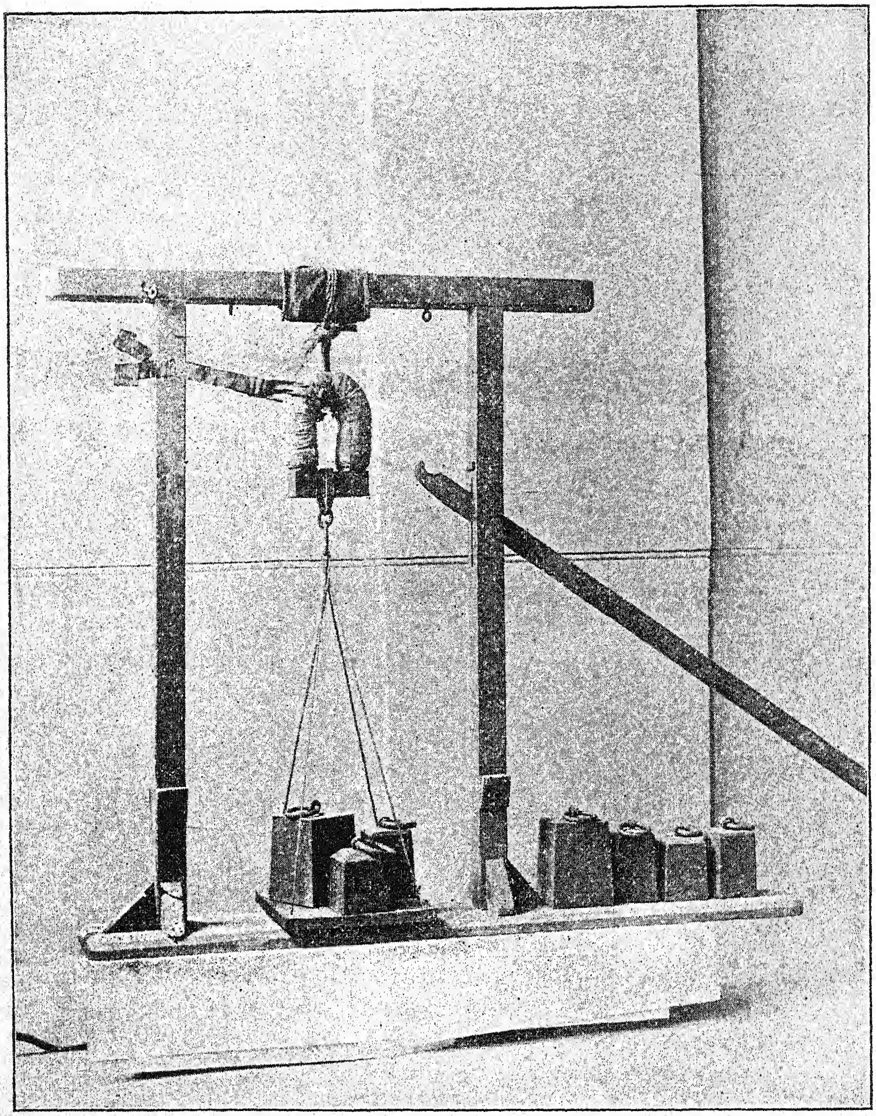
Yes, it was there, and his was the superb insight of genius to detect that startling new fact. He was another Saul hunting for his father's strayed asses and finding a kingdom—another of the immortals selected in some superhuman way to be leaders of the human race—the power-bringers.

Within a year, still neglecting his smithy, Davenport had built his first electric motor, and discovered "the production of rotary motion by repeated changes of magnetic poles," which could be applied as a "moving principle for machinery." His patent of 1837, the first of its kind in America, set all this forth, and was as broad as a papal bull granting a continent to Columbus. It was said in 1891, forty years after the patent had run out, that "if it were in force to-day, upon a fair judicial construction of its claims, every successful electric motor now running would be embraced within its scope."

Possibly by reason of poor insulation, the first little Davenport motor of 1834 did not work very well. Funds were fading away. Nevertheless another motor must be built; so into its insulation around the tiny coils of wire went the narrow strips of the delicate wedding-dress. From that time on, never again was Davenport to know peace of mind, nor was his family to enjoy a quiet home of comfort. It is told that when Palissy, the famous French potter, closed in on the discovery of his beautiful enamel, he tore down the very woodwork lining the walls of his house and wrecked the furniture, to feed the fires of his kiln. Madame Palissy did not quite like it. Can you blame her? In both instances, wifely devotion could go no further. It is a pity loyal Emily Davenport did not live to see how in these later, happier years, the successors of her husband by way of noble amends have brought in countless little electric motors to relieve the burden of drudgery in the household.

The First Electric Company

About this time, Jacobi, in Russia, had also begun to obtain rotary motion from electromagnets, and in 1838, with the help of the Czar Nicholas he propelled a small boat on the Neva at St. Petersburg. But meanwhile Davenport was already employing the first commutator on his motor of 1835; a commutator is the device at the end of the revolving bunch of wires,



PROFESSOR JOSEPH HENRY'S ELECTROMAGNET.

This photograph represents one of the first tests of Henry's electromagnet. Current was brought to the magnet through the heavy copper strips at the left, which were connected to the wire with which the soft iron core was wound. The core was thus magnetized, and supported the weight shown on the platform below—approximately 450 pounds.

called an armature in a motor or dynamo, literally a bunch of nozzles through which the current is collected or directed from each coil as it flies past the exciting poles. Next year he made the memorable advance of building both motors and tracks to show that a railroad could be run quite as well by electricity as by steam.

Davenport was ever as full of ideas as he was short of money. As one of its early passengers and critics he had seen the pioneer steam railroad working since 1831 between Albany and Schenectady. It would seem that he even talked over electric traction, at Albany, with the great Henry, who kindly warned him to go slow when he proposed, in his competition with steam, to build motors up to a size of one horse-power. At all events, when his native State had not one single mile of steam railroad, Davenport, all fire and enthusiasm, not only built his curiously prophetic little model of an electric road, but boldly asserted that such was the better way to do it. The car was shown travelling on a circular track twenty-four inches in diameter. It depended for "current" on primary batteries (dynamo-electric energy not then being available) placed on a tray at the centre of the track circle, with contact through mercury-cups; thus was foreshadowed the central power-house idea of modern operation. Moreover, like the cars of to-day, not only did those primitive cars use the track for the return circuit, but the motors were shunt-wound, that is, the wires in the winding on the field-magnet poles were a "by-pass," through which current was shunted from the armature. Such a motor seemed to perform the feat of "hoisting itself by its own boot-straps," as our forefathers put it.

Beyond this, in order to raise capital for expensive trials and machines, Davenport organized in 1837 his Electro-Magnetic Association, the first electric stock company in America, and probably in the world. Serving the great American public to-day such companies are capitalized at a score of billions. Surely the owners of the "one-hoss shays" might well wait outside the humble Brandon smithy while the blacksmith inventor was planning and building motors and tracks that were soon to show the way in putting horse haulage forever in the "discard." It is part of another story how Davenport in 1839

was the first man to apply the electric motor to printing-presses and to publish, so printed, the first electrical journal; how, too, when he died in 1851, he was applying electromagnets to the vibration of piano-strings—the first production of music by electricity.

After Davenport came a large group of far-seeing men who bravely and cleverly struggled with the problems of electric railroading. None of them realized that their trouble lay in not having a cheap supply of electrical energy, or "current." They depended on current from "primary" batteries in which acids attacked metals, and that method involved, as it does now, enormous expense. Burning up zinc in a battery, for example, could never successfully compete in its results with the burning up of coal under a boiler, whether the steam drives a locomotive or operates an engine in a factory. Unfortunately, none of these early workers realized that the discoveries of Faraday and Henry in magnetic attraction and repulsion could be applied not only to produce Davenport's motor but also the more wonderful machine, the modern dynamo, now called the "generator." No matter how they use it, the great applications of electricity all turn to the generator as the source of their current energy. It might possibly be said without fear of contradiction that had the dynamo been invented twenty-five years or so earlier, the course of history would have been vitally changed.

The Invention of the Electric Locomotive

While the steam locomotive, then entering upon its triumphant career, began to traverse continents with its seven-league boots, the feeble electric locomotive was left to a stern chase for fifty years. The primitive electric car-motor draining chemical primary batteries of their costly supply of vital energy was about as helpless as a baby sucking at its bottle. In Scotland, in 1838, an engineer named Robert Davidson, tried out such an electric locomotive on the Edinburgh-Glasgow Railway. Patents on various modifications of the basic idea were granted in England and the United States, and many pretty little models of the Davenport type were exhibited by wandering lecturers. They rarely took in enough "gate-money" to pay the rent of

BROADWAY, NEW YORK, ABOUT 1863, WHEN STAGE-COACHES WERE IN THEIR PRIME.

the hall in which to show their scientific freaks and curiosities. Perhaps their only success was that they set thinking young geniuses such as Edison.

About 1847–8, a famous American inventor, Moses G. Farmer, who twenty years later did arrive at a clear-cut vision of the dynamo, built an admirable experimental car—using battery power, of course—which carried two passengers. Three

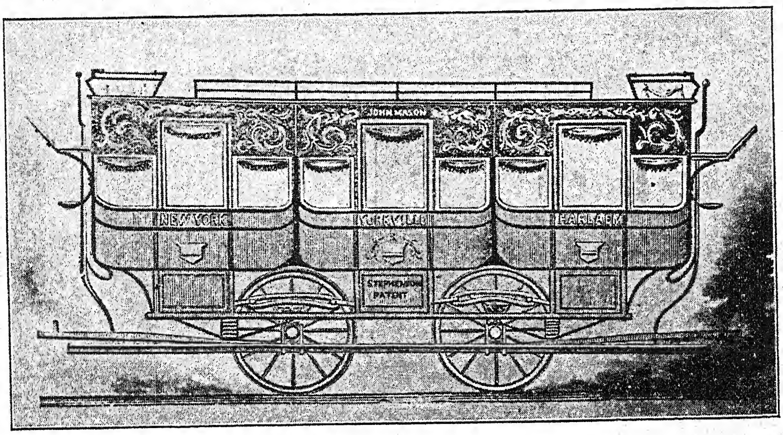
years after, a brilliant man, Professor C. G. Page, successor to the great Henry at the Smithsonian Institution in Washington, ran a car on tracks from that city to Bladensburg, Maryland, using the current from no fewer than one hundred cells of primary battery. He actually got up to a speed of nineteen miles an hour before the jars of the overworked batteries cracked under the unendurable strain. That was the end of Page's electric car as well as of his costly attempts to get to Baltimore. Forty years elapsed before Leo Daft brought a successful electric car to the Maryland city, and sixty years before such cars shuttled swiftly between it and Washington in regular hourly trips.

Early Street-Car Lines

It is to be noticed that all these early workers and experimenters dealt with railroads and not with street-railways of any kind. Utterly unknown then were such modern necessities as the "trolley," the "L," and the "Tube," all of which still lay many years ahead. Perhaps they were not greatly wanted by our more tranquil forebears, when land travel, if not afoot, was done on horseback or behind the horse in a coach, and sometimes, even in towns of good size, by oxen. Paris, one of the very first cities in the world to have a public system for lighting its streets, was also the first city to enjoy the luxury of an omnibus, or "carryall," something akin to the stage-coach that plied on the ill-paved robber-haunted highways across France. With Pascal, in 1662, or Baudry, in 1827, may have originated the idea of the "omnibus," and thus also of the street-car, which is nothing more or less than a "bus" on rails. Another fruitful idea was embodied in the light railroads of the two Outrams, father and son, built in England for mines, and nicknamed "tramways" after them.

In 1830, the sprawling young city of New York had proudly reached a population of 200,000. Lively, active people they were, increasing by thousands and pushing "up-town" at the rate of several "blocks" each year. They must have street-transportation lines out to their newer suburbs. Hence that year the famous Broadway stages were started from the Bowling Green. Not so very long ago one could still experience the

perils and hardships of a ride in one of those gaudy old "stages," in appearance much the same as a Barnum circus parade-wagon, and about as comfortable. But ambitious Manhattan Island had no sooner thrilled with the excitement of dashing along by omnibus at six or eight miles an hour than, in 1832, it had at its service the first horse street-car line in the world. It was called the New York and Harlem Railroad, organized in 1831,



THE "JOHN MASON," USED ON BROADWAY, NEW YORK, IN 1832.

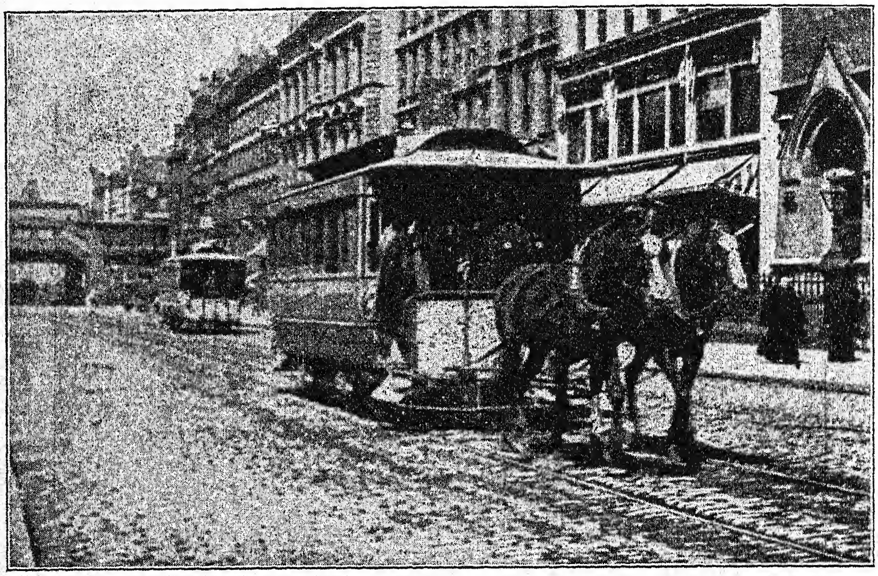
The vehicle is frankly modelled after the stage-coaches of the day.

and it extended a few miles up Fourth Avenue from near the City Hall to Murray Hill, where now stands the Grand Central Terminal.

Thus in the "John Mason," as the street-car, in honor of the first president of the company, was named, the omnibus and the "tramway" had been merged in the one vehicle on flanged wheels. As it jogged over the uneven rails before the inquiring eyes of the citizens of New York it presented the funny appearance of a couple of "stages" squeezed together. Moreover, by a strange coincidence, this first street-car bore on the panel of its door the words "Stephenson's Patent." That trade-mark, however, applied not to the great Englishman who had harnessed steam for traction, but to a clever American mechanic, John Stephenson, first of the horse-car builders, a man of ready ingenuity whose business still bore his name full

fifty years later. His jolting juggernaut and the strap-rails laid on stone ties constituted the first passenger street-railway.

It was not until nearly twenty years later that another street-car system made its appearance in New York. Then the present trolley era began with horse and mule, and between

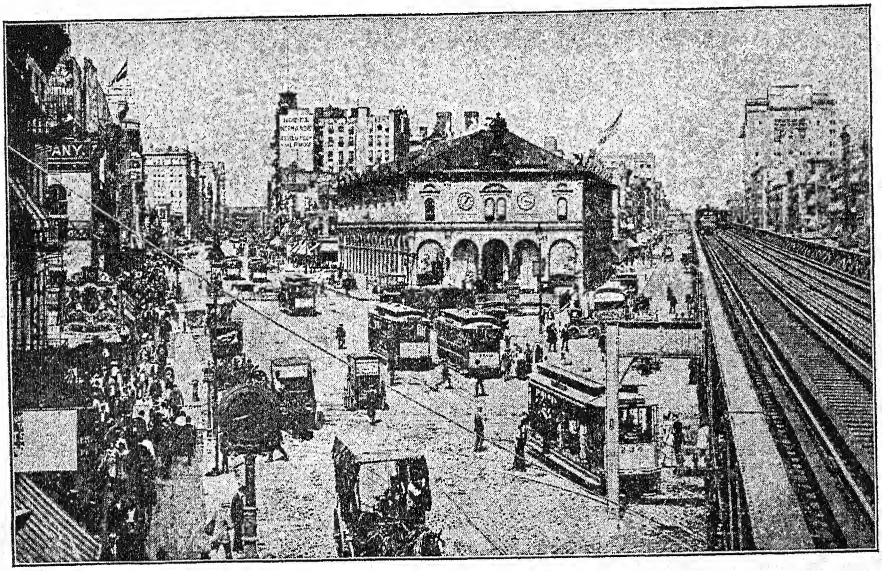


NEW YORK IN THE HORSE-CAR DAYS OF THE EIGHTIES (FORTY-SECOND STREET).

1850 and 1855 half a dozen American street-railways were built, although not until 1860 did Europe get its first street-railway, when an erratic American, George Francis Train, secured a franchise to operate one at Birkenhead. By that time, the United States had nearly forty such railways, and over eighty more were built between 1860 and 1870. When the first census of street-railways was taken in 1890, no fewer than 769 were in operation in the United States. That great jump forward was due wholly to the fact that electricity had at last come into its own. In furnishing energy and service for the street-car, the horse, cable, and steam or compressed air were now obsolete and left behind.

It has been proved beyond all question that no agency but

electricity can handle the surging millions of people massed in the great cities of our twentieth century. One hears a good deal about "jitney" gasolene buses as competitors of the trolley. Any one could soon figure out how many scores of thousands of jitneys would be needed in New York to carry those of its



NEW YORK (THIRTY-FOURTH STREET AND BROADWAY) IN THE NINETIES.

The street-cars were hauled by cable and the elevated trains by steam locomotives.

6,000,000 citizens who must travel daily. From them and from people coming into town are collected every twenty-four hours more than 6,000,000 fares, giving the right on most lines to journey more than fifteen miles for five cents at a speed of twenty miles an hour.

"The Most Important Discovery of Modern Times"

One would like to tell more about the dynamo because it is the source of all current for its counterpart, the motor; but that is told in the chapter on "The Rise of Electricity." No sooner was it realized that by spinning the armature coils of wire in front of the electromagnets a ceaseless inexhaustible supply of cheap current could be obtained from them, than all the modern electrical arts sprang into being. To this is due the

remarkable fact noted above that, when electricity became available soon after 1870, the street-railway industry increased sixfold in the twenty years to 1890. Sometimes the generator which delivers current to the distant car is driven by a steam-engine, sometimes by a gas-engine, often by a water-wheel. The result is the same. We have the generator driven by power and developing electricity and then the motor receiving the electrical stream and developing mechanical or motive power. Clerk Maxwell, the great British physicist, called the dynamo "the most important discovery of modern times." So far as traction was concerned, however, it was only an improvement on what Davenport, Davidson, Farmer, and others had already done. To them goes the credit for the pioneer work; without their indefatigable genius the activity of the generator might have been limited. On the other hand, with the coming of the generator we reached an absolutely new starting-point. In the same way, when artificial gas was piped for lighting, it displaced all that had before been done by oil lamp and tallow candle.

Stephen Field Applies the Dynamo to Street-Railways

About 1875, a poor mechanic, George Green, of Kalamazoo, Mich., appears to have built one of the old-fashioned pre-dynamo street-cars, with an overhead wire from a battery. Three years later he built a bigger car, and, in 1879, at the dawn of the new era, he secured a patent with such broad trolley claims as to make him look like a Moses at the frontier of the Promised Land. In 1877, came Stephen D. Field, who, living in hilly San Francisco, thought that electric power could be used instead of the noisy expensive cable, employed to haul cars on the stiff inclines of that city. For such severe work, equal to that of an office-building elevator, the cable has many merits. It can still be found on a few mountain roads, but even then the electric motor frequently drives the cable drum.

Stephen D. Field, a nephew of the famous untiring advocate of the Atlantic telegraph cable, was a talented, harum-scarum inventor, and as courageous as his uncle. He ordered one dynamo from Europe for his experiments, lost it at sea, then

bought another, and soon found himself bankrupt on the shores of the Pacific. Nothing daunted, the young engineer returned East full of his novel scheme, there to round up friends and funds. In 1874, he filed in the United States Patent Office what is called a "caveat," followed up by a regular "application" the next year. These disclosed plans for an electric railway, using current from a stationary dynamo, delivered through a third rail or insulated conductor to the car-wheels and traffic rails, which, divided into sections, formed the return circuit. Just Davenport over again, with improvements.

At the same time, the Siemens firm of Berlin, one of the first great builders of dynamos and motors in Europe, were operating at a local exhibition near the River Spree a little electric car, resulting from some abandoned experiments made by Doctor Werner Siemens. Their little electric locomotive, with third-rail supply and track return, pulled briskly for a third of a mile its train of three cars and twenty passengers at a rate of eight miles an hour. It was as much a world sensation as were airplane flights before the Great War. Similar ventures to that introduced by the Siemens in Berlin were soon in operation at exhibitions in Brussels, Frankfurt, and Düsseldorf. On May 12, 1881, a permanent line, the first of its kind, was put in operation from Berlin to Lichterfelde; but it left out the third rail, the two track-rails being the plus (+) and minus (−) of the little system. And then the rush began in the Old World.

Overlapping the plans of Field and the experiments of Siemens came the work of Thomas A. Edison, unwearied and fresh from his glorious triumphs with the quadruple telegraph, the carbon telephone, the phonograph, the incandescent lamp, and a few other such miracles. The great inventor could not resist the opportunity of further success offered by the electric railway.

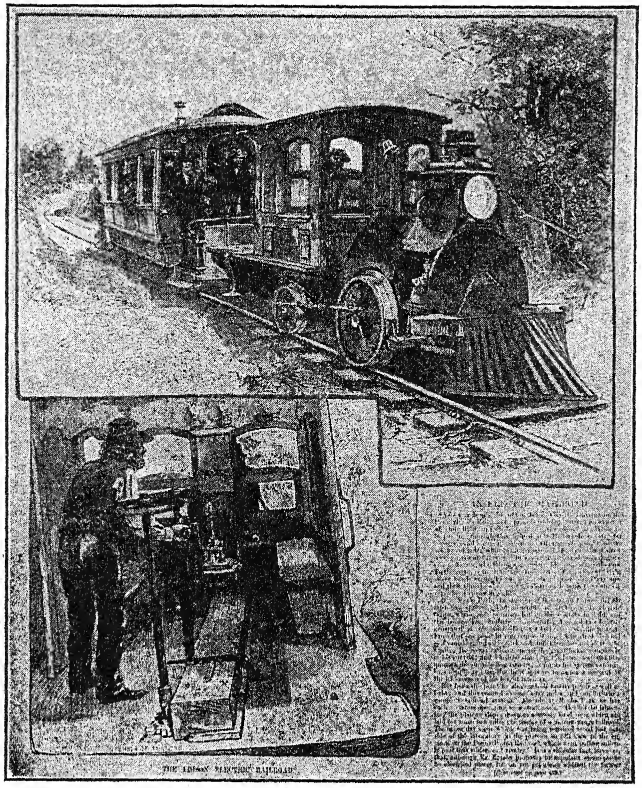
Edison Experiments with Electric Traction

In the spring of 1880, trying out some ideas conceived over a year before, he built at the back of his Menlo Park laboratory an interesting little railroad. At this time he was still plunged deep in all the problems of his electric-lighting system. Edi-

son's first locomotive was, in fact, merely a lighting dynamo used as a motor, laid flat instead of set upright; and the power from the armature shaft was simply applied to the car-axle by friction pulleys, afterward changed to pulleys and belts. The two track-rails were the conductors, one set of wheels being insulated. It is noteworthy that the motor had a capacity of not less than twelve horse-power, and that in describing the primitive "road" the New York *Daily Graphic* published a sketch of a hundred-horse-power locomotive which Edison even then, with wonted audacity, was planning for the Pennsylvania Railroad to ply between Perth Amboy and Rahway. In fact by the time President Frank Thomson of the Pennsylvania came out to risk his life on the ramshackle "road" at Menlo Park, Edison, to use his own language, "was getting out plans to make an electric locomotive of 300 horse-power, with six-foot drivers, with the idea of showing people that they could dispense with their steam locomotives." Henry Villard wanted that locomotive for the wheat-fields and the mountain divisions of his grand new Northern Pacific Railroad. Of one of the demonstration trips Grosvenor P. Lowrey wrote: "The train jumped the track on a short curve throwing off Edison's assistant, Kruesi, who was driving the engine—with his face down in the dirt. Edison was off in a minute, jumping and laughing, and declaring it was a most beautiful accident. Kruesi got up, his face bleeding, and a good deal shaken; and I shall never forget the expression of voice and face when he said with some foreign accent: 'Oh! yes, pairfeckly safe!'" That was the spirit which carried the new idea to victory. Speaking of some other advances of the kind at that time, Edison remarks: "In the same manner I had worked out for the Manhattan Elevated Railroad a system of electric trains, and had the control of each car centred at one place—multiple control. This was afterward worked out and made practical by Frank Sprague." We shall speak of this later.

Electric-elevated railway practice was, as a matter of fact, first carried out in June, 1883, under the Field and Edison patents at the Chicago Railway Exposition, around the outer edge of whose gallery, over a three-foot gauge-track, ran "The Judge" locomotive of about fifteen horse-power. This was the first

electric railway constructed in America for business purposes; and its surprising success was a great advertisement. The road issued regular railway tickets and carried no fewer than 26,805



From Harper's Weekly, July 15, 1882.

EDISON'S ELECTRIC LOCOMOTIVE WITH WHICH HE EXPERIMENTED AT MENLO PARK, NEW JERSEY, IN 1882.

passengers in three weeks over an aggregate distance of 446 miles. Rebuilt at the Louisville Exposition the same year, the feat was repeated on the same scale. Several aspiring young inventors lent a hand in assembling it. One of them, Frank B. Rae, afterward built many pioneer street-railways. Another was C. O. Mailloux, now president of the International Electro-Technical Commission.

The Invention of the "Trolley"

Charles J. Van Depoele, born in Belgium, in 1846, acquired his mechanical and electrical knowledge under the guidance of his father, who was master mechanic in the railway shops of East Flanders. Fascinated by the batteries lying around the shop benches, young Van Depoele had soon mastered so thoroughly the principles of electricity that when only fifteen he operated a crude electric light with current from forty cells. But his father, impatient with such pottering, insisted he should have a real trade. Evident artistic ability led to his being apprenticed to a Paris cabinetmaker noted for his carving of altars and statuary. This did not hinder the young fellow from taking an electrical course at Lille, France, where his family now lived; here his enthusiasm aroused the interest of the teachers, although it continued to give offense to his father. Sturdy young Van Depoele, visiting an aunt at Antwerp in 1868, and seeing his hopes blocked at home, slipped quietly away from that seaport and sailed for the United States. He headed for Detroit, which was then making its mark in furniture just as it has later done in automobiles. Being an artist to his finger-tips, and knowing all about church fixtures, from pews to reredoses, he joined hands with a compatriot and there founded a factory which at times employed as many as 200 highly skilled craftsmen. He did so well that he was able to bring the old people to America. Then, in 1877, he took an amusing revenge on his father by turning over to him the active management of his prosperous business. Freed from this responsibility, with unconcealed delight he spent his profits from the carving of saints on experiments in electric-lighting. Soon he evolved a novel dynamo, and with its current lit up a big arc-lamp, whose lurid glare in the overhanging fog from the lake caused a nervous citizen to turn in a frantic fire-alarm. About 1878, Forepaugh's famous circus came to town and Van Depoele lit it up, making an immense sensation; in 1880, he had one of the earliest American electric-light companies going at full blast. A few years later the company began to dabble in electric traction, and in 1883 it built two little roads, one of which, toward the end of the year, ran for fifty days at the Chicago

Interstate Fair. Thus began Van Depoele's share in a new era of development, with inventions of which the United States courts said later: "Several patents cover highly meritorious inventions which have largely contributed to the successful practical operation of the trolley roads throughout the country." He built early roads in all parts of the United States and Canada, and when he died, in 1892, he was the grantee of some 250 United States patents in all branches of electricity.

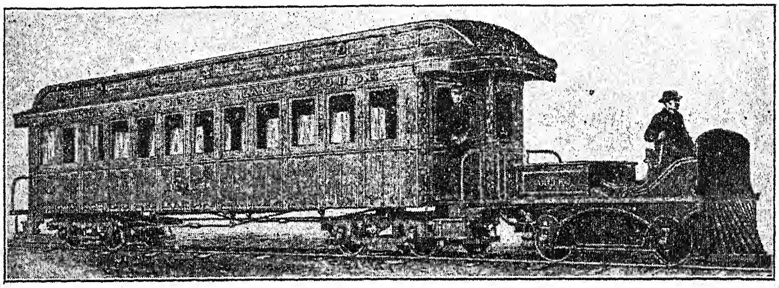
Many improvements have been made in electric railways since those days, but his idea of the little wheel at the end of the trolley-pole—dubbed by the poet Holmes "the witches' broomstick"—still survives as a running contact under the overhead wire as the most economical and efficient method of picking up the current from the distant power-house.

Curiously enough, although Van Depoele has been called the "Father of the Trolley," he did not coin the word. It traces back to another pioneer, John C. Henry, a young telegraph operator, with courage and ideas of his own, one of which was that of suspending the supply conductor wire over the track by means of span wires supported in turn by the poles along the line. Henry's first travelling contact for a line out of Kansas City to Independence, some ten miles away, was a little four-wheel carriage, which gripped onto and ran along the under side of the overhead supply wire that fed current to the car motor. It was virtually a baby's toy carriage turned upside down, and was hauled by a flexible cable, string fashion, connecting to the motor, which thus trollied it along. At first it was called a "troller." Then the street-car men and the passengers changed it to "trolley," and "trolley" it has ever since remained as a general popular name for all electric street railways.

The Experiments of Daft and Short

Inventors and their efforts were rapidly increasing. One or two stand out in the historic perspective of the new art, and their efforts should briefly be noted since they began to mark out distinct lines of either experiment or success. Thus there was Leo Daft, a clever English photographer, who took the first large views made in America, and later gave New York city its

first power circuits for operating electric motors. Picturesquely he named his first electric locomotives after Morse, Volta, Ampère, and Benjamin Franklin. Beginning in 1883, Daft did some very interesting work on several roads, including the New York Elevated, and one, an Adirondack hill-climber, on Mount McGregor, where General Grant died and where regular railroad coaches were hauled by electric power for the first time.



From Martin's "Story of Electricity," published by Johnson and Co.

DAFT'S AMPERE-ELECTRIC LOCOMOTIVE.

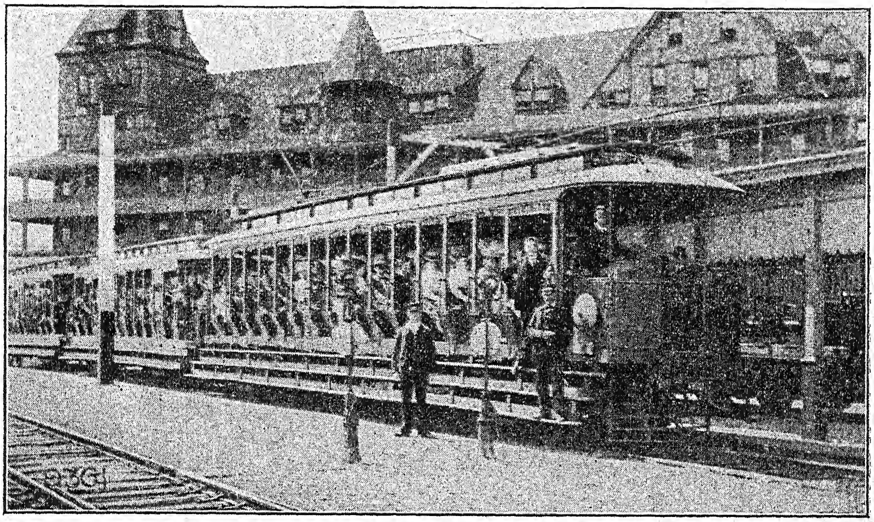
The driver of the locomotive sat in the open, and situated directly in front of him were three switch-boxes.

Early in the spring of 1885, Daft began to equip the Hampden branch of the Baltimore Union Passenger Railway Company. This had a third rail with track return, and it was probably the first regularly operated street-railway in the country. The conditions of the contract required satisfactory operation before payment. A distinguished scientist said that only a knave or a fool would enter into such an undertaking; but the faith of Daft and his backers was strong. They blazed the way for other "fools" crowding in behind them.

In the early part of 1885, Professor Sydney Short, a young physicist at Denver University, began an interesting number of experiments out in the foot-hills of the Rockies. The "series" system was used, in which, as in the early arc-lighting, a constant current went through all the motors in series succession on the line. After a while it was found that the "multiple" was the better way to do it, with the motors, across the current circuit, like incandescent lamps; or, to use a simple comparison, like the rungs in a ladder between the two uprights. But Short,

undiscouraged, went on to great successes in "multiple" trolleys here and in England. He was very successful also with gearless motors, in which all energy-wasting gears between the motor armature and the driven car-axle were left out.

Another method of operation and its crude "try out" must here be mentioned. Short had worked with a "conduit" system, or concealed feed-rail, to prevent any fatal human contact with the really deadly high-voltage current he was using. Evidently this also avoided the use of the overhead-wire method which, though it had many objections, was long unfairly damned in the sensational newspapers as the "deadly trolley." About this time, watching the successful cable street-railways of the day, with cars, like monster buckets, hooked on to the stout wire rope travelling in the slotted road-bed, two young patent lawyers, E. M. Bentley and W. H. Knight, put into operation a proposed rival. It may be regarded as the protoype of all the "conduit" street-railways operating successfully to this day on many busy thoroughfares from which the city fathers have barred the trolley overhead wires. The two-mile stretch



THE SPRAGUE "MULTIPLE-UNIT" SYSTEM.

At first, Sprague used ordinary street-car controllers, as here shown. The motorman manipulated a master-controller and thus controlled the motors on all the cars in the train.

of the Bentley-Knight system on the East Cleveland, Ohio, road gave new meanings to such words as "plough," "slot," "shoe," and "conduit." Operating quite well even through the deep snows of the Lake shore in the hard winter of 1884–5, it also may claim to have been one of the earliest lines to collect a five-cent fare as a commercial electric street-railway.

Frank Sprague and "Multiple-Unit" Control

A brisk young lieutenant from Uncle Sam's navy now burst impetuously into the electric-railway field. As jury secretary of the famous Electrical Exposition at the Sydenham Crystal Palace, England, in 1882, Frank Julian Sprague had to use the smoky old London "Underground." He soon conceived the idea of running it electrically, as it now is run. His clever plan was to have rigid rails overhead as well as underneath the car, all in one plane, with current contact with the overhead rails by means of an upward-pressing wheel or cylinder. With that began an inventive career unsurpassed in brilliance and success. Sprague came at the moment when the electric railway needed some great achievement to sum up all that had been done before, to enlist capital, and to shape things for the long future. Returning to America in 1883, Sprague entered the service of Edison, then improving his incandescent-lighting system. But he was too full of his own ideas to be interested in those of any other man, or to bother about orders from anybody. He cut loose! Napoleonic in temper and character, his moves and advances were made so swiftly that almost overnight the central station industry found itself with the gift from him of the motors so badly needed for its lighting circuits.

Sprague had as business partner Edward H. Johnson, who had been associated with Edison; the two kindred spirits flung themselves violently into the trolley industry with no delay and precious little money. Some of Sprague's first work was done on the Manhattan "L"; but mischance would have it that the great financier, Jay Gould, a little man physically, stood near the car-controller while the test car was being operated. An exposed safety-fuse "blew" with a startling flash. Gould tried to jump off at the risk of his life, and the "subsequent proceedings" did not interest him at all.

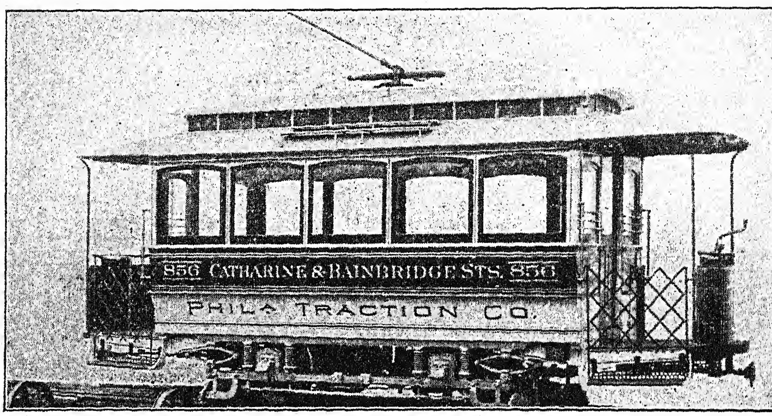
Nothing daunted by ill-luck, Sprague at once took on a street-railway job and soon had some minor work done. His great opportunity came at Richmond, Virginia, and the capital of the old Confederacy was assaulted with a Sprague determination that brooked no denial. The contract taken there would have been staggering to any but a sanguine inventor willing to gamble the very last dollar in backing up that in which he believed. Completion was called for in ninety days of a street-railway with twelve miles of track, a central power-plant, the overhead line, forty cars with eighty motors, one on each car-axle, and all the needed controllers and appurtenances. This was nearly as many motors as were then giving uncertain railway service throughout the world. Moreover, grades of eight per cent. were to be tackled, and no fewer than thirty of the cars were to be in use at one time.

The difficulties to be overcome were stupendous. The young inventor had barely signed the contract when he was stricken with typhoid fever, and he had mighty little shot of any kind left in his locker when, in February, 1888, the road went into commercial operation. But its success was instantaneous, as was also the effect on the public, on capital, and the whole range of electrical application. Watching those mysterious cars climb up the steep slippery grades of Richmond, an old colored man ejaculated his fervent blessing: "Fust dey freed de darky, and now dey freed de mule!"

"Tinker, tailor, soldier, sailor, ploughboy, potboy"—runs the old song snatch. And now just such another curious grouping had occurred around the trolley. Blacksmith, telegraph-operator, photographer, navy officer, carver of furniture and wooden saints, patent lawyer, college professor had been needed in the combination of "all the talents" to which is owing the modern electric railway. Whatever may be the method of latter-day operation, including one or two variations and developments still to be noted, fundamental principles and appliances were now all clearly established, foreseen, or promised. Little or nothing could be added except by way of achievement.

Mark Twain said that without differences of opinion there could be no horse-races. Without radical differences of opinion, the modern street-railway would not have been developed.

Many things had to be tried before they could be discarded. One was the "series" method of operation. Another was that of carrying storage batteries on the cars, for current supply, so as to get away from use of all overhead or underground wires and contact. Julien, Reckenzaum, Arnold, Edison, and others did their best to make this latter method successful, but it failed.



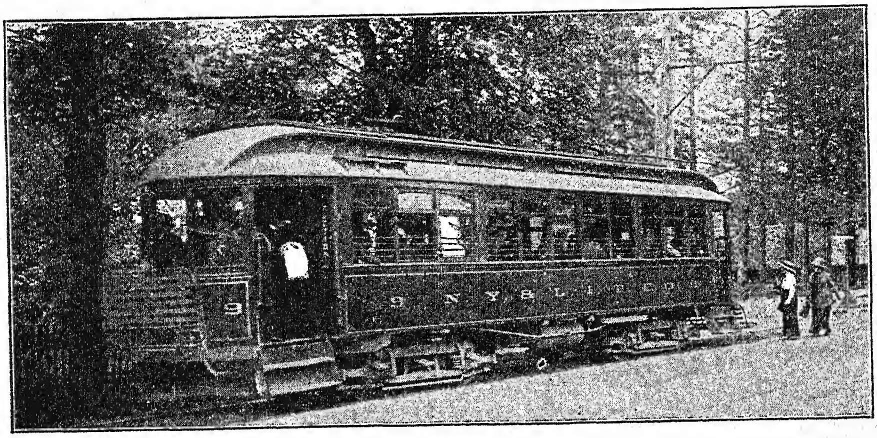
Photograph by J. G. Brill Company.

ONE OF THE FIRST TYPES OF ELECTRIC TROLLEY-CAR.

Arnold, who as a boy had built an operative steam locomotive when only sixteen years old, was one of the earliest men to apply alternating current to regular railroads; a wonderful development. Another ingenious plan, still favored to-day, is that of sticking to the overhead wires but giving up the use of the track as a return conductor. As far back as 1882, Doctor Finney, of Pittsburgh, devised such a scheme for omnibuses and street-cars. It has been used in a scattering way ever since; and at the time of this writing the "trackless trolley" has been adopted for the suburbs of New York city.

At first electric street-cars ran singly, usually with one motor mounted over the floor or chassis. Then the motor was slung underneath, on the car bottom or the axles. Sprague hit on the now-universal "wheelbarrow" method of motor suspension in 1885. Pretty soon, owing to the enormous growth of traffic and increase in weight of cars with steel-girder frames, two motors were the approved practice, the car often hauling one or two

"trailers," which had no motors. A next step was linking the cars, even on the streets, into long trains, a dangerous practice, but the only way to carry the crowds of passengers unless there are elevated roads or subways that free the thoroughfare of such traffic. The train method has been a favorite with the numerous "interurban" trolley systems supplanting or supplementing ordinary steam railroads across country.

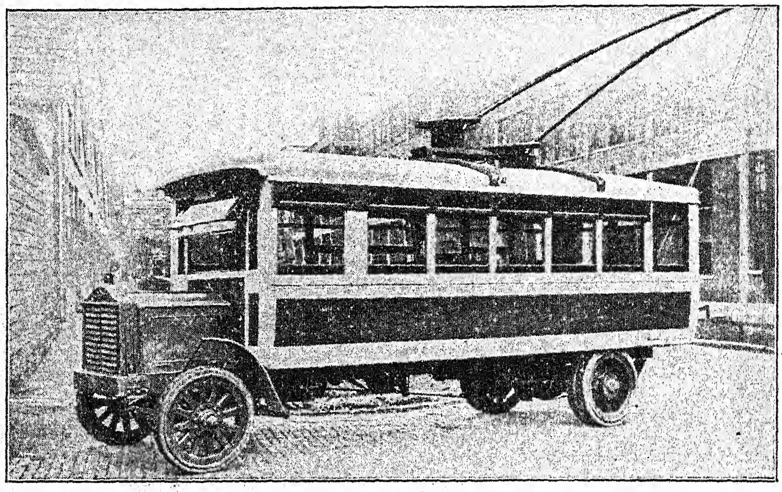


MODERN TROLLEY-CAR OF INTERURBAN TYPE.

As we have seen, the elevated railway and the subway both antedate the electric street-car. Few cities ever adopted the "L," and those that did were compelled to endure its many disadvantages. At best a makeshift and not a great invention, the "L" will probably soon disappear, although it has done great service in sorely congested cities like New York, Berlin, Philadelphia, Chicago, and Boston. The more important inventive and engineering feat was the subway.

But, for the "multiple control" or "multiple-unit" system, credit at least is due to the "L" as also to the versatile, energetic Sprague, who offered it for New York in 1891, and in 1897 actually put it in operation on the South Side Elevated of Chicago. As Colonel H. G. Prout remarks in his life of George Westinghouse, who did as good work in using compressed air for multiple control as he had done in the air-brake: "It is elementary in the art of land transportation that when the volume

of traffic is large enough there is gain in massing the cars into trains." Agreed, but the old-style locomotive must be dispensed with and the motive power placed in smaller units under each car. Then a highly novel and satisfactory condition arises if only the motors can but lock-step and all go off together. The train can start more quickly, stop more quickly, spread



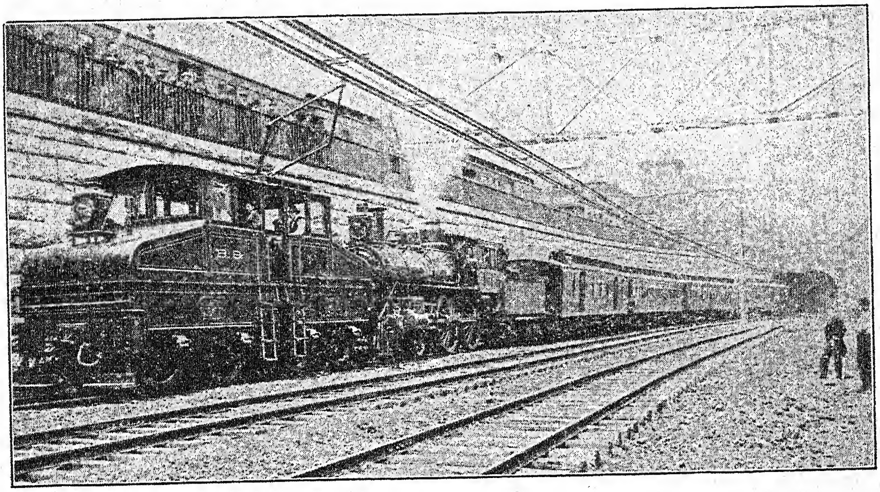
THE TRACKLESS TROLLEY OMNIBUS.

Vehicles of this type are used where it does not pay to lay tracks and where the traffic is not dense. The operating costs are lower than those of a track trolley-car. The seating capacity is about thirty. This particular 'bus was built for Detroit, Mich. It follows gasoline 'bus rather than street-car design.

out its weight over more track, use less current for the work done, and "speed up the schedule" for all the headlong travel of city and suburb. Sprague in applying electric elevators to office-buildings had adopted a plan of motor control from a distant "master" switch. Using to begin with, at Chicago, ordinary street-car controllers, such as you see the motorman operate in much the same way a steersman on shipboard does his wheel or tiller, Sprague brought the operation of all of these, no matter how many or how long the train, to a master controller handled by one man. In this, his principle harked back to the massing of power and the instant application of the whole energy of it, exactly as though it were concentrated in a big locomotive instead of being distributed in small units.

THE NEW YORK "TUBES"

The application of such control in the electropneumatic form is best seen on the great subways of New York city, a system in extent and travel far beyond anything else in the world, and wholly impossible without electric traction. Other subways in Boston, Paris, and such cities, have followed its example, while



THE FIRST STANDARD-RAILWAY ELECTRIC TRUNK-LINE.

Baltimore and Ohio electric locomotive hauling the first train under electric power in 1895.

in London similar tubes, under American enterprise, have been put in operation 300 feet underground. Downward, rather than upward and double-decking the streets, does the modern city find the possibility of living and travelling in layers, much as they did in the catacombs of ancient Rome.

Although as long ago as 1868 forty-two citizens of New York formed an underground railway company to build a line from the City Hall to the Harlem River, it was not until 1904 that the first of the "Tubes" got into operation. Since then the growth of the network has been incredibly rapid, and it is all tied in with the "L" system as well as with river tunnels and the main railway trunk-lines. There are over 600 miles of "L" and Tube in the city, of which the Interborough Company's

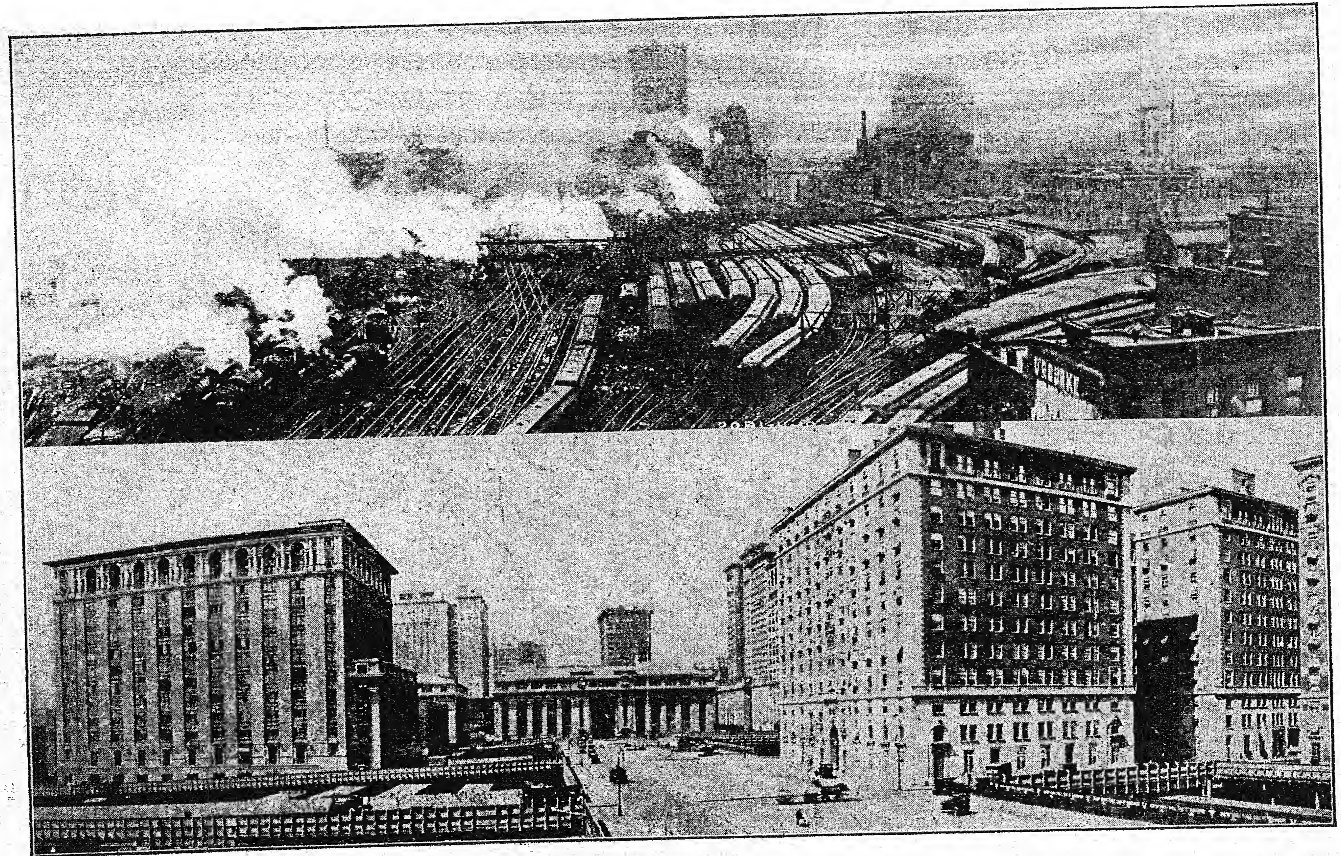
subways total no less than 222 miles. And yet it is said that if the mileage of track could at once be doubled, people would still suffer the discomforts of overcrowding during the "rush hours."

One means of relief is suggested by "travelling sidewalks." At the Columbian World's Fair, outside Chicago in 1893, a motor-driven endless circular sidewalk was successfully operated on a long pier, where the boats landed sightseers from the city. It had two, or twin, platforms and some seats. Stepping first on the slower "walk," the passenger could either stay there, or hop on to the other going at twice the rate, six or eight miles an hour, equal to the speed of an ordinary street-car. This was copied at the Paris World Exposition of 1900, with American motors under the decks; the elevated "sidewalk," which one could board at frequent stations, gave the passenger a fine view of the show and of Paris itself. More than once it has been seriously proposed to introduce the "flying" pavement into New York city, and the prediction is made that all the people who use it will jump right off to the faster "belt" as they get on the slower one.

When it is noted that the cars in Greater New York carry yearly twice as many passengers as all the steam railroads of the United States, it explains the confidence of electrical engineers that in a few years there will be no steam railroads left. A rising member of the profession once predicted that ten years later there would be no steam locomotives plying between New York and Boston. Andrew Carnegie listening, nodded his head approvingly, but said with Scotch canniness: "Weel, it's fine for young men to prophesy but they shouldn't fix dates!" The process is already well advanced, and it involves no real changes in methods or conditions. Such invention as is needed is aimed rather at bringing the art abreast of the larger scale upon which everything has to be done, and this readjustment begins at the power-house itself.

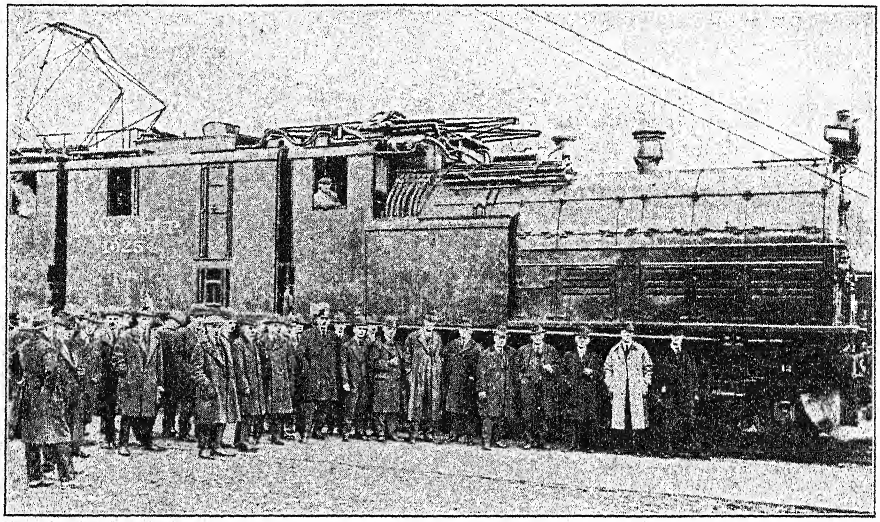
Driving Trolley-Cars from a Central Power-House

The early reciprocating steam-engines driving direct current generators of a few hundred horse-power have been left behind by steam-turbine units—"turbo-generators"—of over 50,000



GRAND CENTRAL TERMINAL, NEW YORK, BEFORE AND AFTER ELECTRIFICATION.

horse-power capacity, twice as efficient and occupying less than half the space. Formerly the power-plants were non-condensing and stood on expensive ground at the city centre. Then they were moved to the water's edge where condensing water was free and gave cheaper current in greater volume. Now they are



Courtesy of General Electric Company.

ELECTRIC LOCOMOTIVE OF THE CHICAGO, MILWAUKEE, AND ST. PAUL RAILWAY.

The Chicago, Milwaukee, and St. Paul Railway is operated by electricity generated by water-power. The locomotives as they coast down-hill "regenerate" a certain amount of electricity on their own account, which is returned to the line. Electric meters record the amount thus returned and the road receives credit for it. Electricity keeps its own books.

being put right at the pit's mouth so that no coal is carried, but its power essence is invisibly loaded on to a wire. But most notably of all, water-power is being enlisted so that coal of ever-increasing costliness is saved. In 1914, coal for our railroad locomotives cost $235,231,481; in 1920 it cost just three times as much—nearly $700,000,000. Of course it is expensive to develop water-power, but a harnessed cataract is cheap to manage and maintain. A coal-mine is soon plundered of its wealth, but Niagara has been tumbling millions of horse-power over the Horseshoe precipice for tens of thousands of years, and we have barely begun to tap its inexhaustible supply of energy

and power. Getting in illimitable quantities the "white coal" of all such water-power, we can hurl their lightnings across a continent. Where low voltages or pressure of electricity could be utilized only a few score miles with the direct current, "potentials" have been raised by means of the alternating current so that line pressures have been carried up to 100,000 and 250,000 volts; and power is already utilized several hundred miles from the spot at which it is generated. The fog-banks from the Pacific Ocean caught on the Sierras spin the buckets of the turbo-generators, which convert the sparkling dewdrops into power for the electric locomotives of Southern California. The melting snows of the Rockies revolve the car-wheels of distant Denver. Similar conversions of sources of energy to electricity are going on not only in the leading countries of Europe, but in Central Asia, India, Japan, and Australia.

At present, but four per cent. of main-line railroad has been electrified in America. If fifty per cent. of the 270,000 miles were converted there would be, to mention one item, an annual saving, chiefly in coal and tenders, of no less than 73,000,000,000 ton-miles. That volume of traffic is equal to over ten per cent. of the total revenue-producing freight handled. Meantime the good reasons that have shut the steam locomotive for human travel out of New York city are of equal force everywhere.

The electric locomotives supplied for the Chicago, Milwaukee, and St. Paul road were magnificent creations, the largest passenger-locomotives in the world, rated at 4,200 horse-power. Moreover, as they drop down-grade they "regenerate." That is, the motors become dynamos feeding current back into the line, so that they not only help brake their own descending train, but generously send out energy and give a lift-up grade to some sister train heavily climbing the mountains miles away. The actual saving in the total power consumption on the St. Paul road by this is from ten to fifteen per cent.

What would Thomas Davenport say of all this? Does it not outrun his boyhood dreams a century ago? Yet did he not foresee the supremacy of electric traction?

CHAPTER IV

THE RISE OF THE AUTOMOBILE

"IT will be possible to construct chariots so that without animals they may be moved with incalculable speed."

This prediction, 500 years before Watt's invention of the steam-engine, was made by Roger Bacon, the English philosopher and man of science who was imprisoned for ten years because Englishmen believed he was a magician in league with the devil.

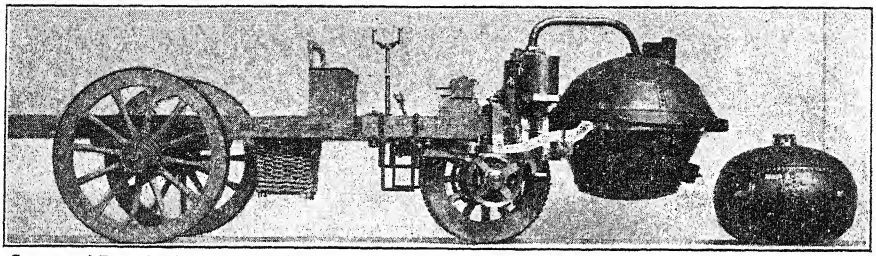
And Mother Shipley, in England, prophesied in rhyme that "carriages without horses shall go."

Soon after Watt began his work on the steam-engine, Doctor Erasmus Darwin, a great English philosopher, thus poetically urged him to build steam wagons:

"Soon shall thy arm, Unconquered Steam, afar
  Drag the slow barge, or drive the rapid car;
On, on wide waving wings, expanded, bear
  The flying chariot through the field of air;
Fair crews, triumphant, leaning from above,
  Shall wave their fluttering 'kerchiefs as they move,
Or warrior bands alarm the gaping crowds,
  And armies shrink beneath the shadowy clouds."

Perhaps Watt was too busy perfecting his engines to be led into any such bypaths. He did state in his patent on the double-acting engine, granted in 1782, that his invention "might be applied to give motion to wheel vehicles." But up to the time of his death, thirty-seven years later, he opposed attempts to use his engines for road vehicles, and even tried to prevent William Murdock, who worked for him, from carrying out the idea. Murdock, who had a will of his own, nevertheless built a vehicle driven by a one-cylinder steam-engine, which he ran successfully in 1784, and which is now in the British Museum in London.

This is not the first automobile of which we have a record. Twenty years earlier, while Watt was improving the steam-engine in England, Nicholas Joseph Cugnot, a French captain of artillery, was trying to discover some way of moving heavy cannon more rapidly than was possible by horses. He spent some years in making engines and mounting them on wheels. By 1769 he had built three steam vehicles, the last of which was tested under the direction of the French minister of war.



Courtesy of Deutsches Museum, Munich.

CUGNOT'S STEAM CARRIAGE OF 1769.

This steam carriage carried four persons at a speed of two and one-quarter miles an hour on a common road. It was really what we would call a tractor, because it was designed to haul artillery. The steam pressure was insufficient to drive the vehicle longer than fifteen minutes.

It was a three-wheeled tractor, designed to draw field-guns. A big boiler hung out in front, and there was an engine with two cylinders over the front wheel. All this weight carried on one drive-wheel, which was also used for steering, was bound to overbalance the machine in front and make steering difficult. The trials came to a sad end when the tractor ran into a wall. This so discouraged Cugnot that he never rebuilt the machine, and at the early age of forty-five he died in poverty.

The First Steam Vehicles

Three years after Watt patented his double-acting engine in England, Oliver Evans, in 1785, built the first high-pressure non-condensing engine in this country, and he sent copies of his patents to Englishmen, including Richard Trevithick, who made a four-wheel steam coach in 1802. The engines built by Evans were so compact, simple, and light that they opened the way both for the railroad locomotive and for the light steam carriage that, a century later, became very popular in America.

Evans devised many ways of using his new steam-engines. His application of them to mills and boats is described in the chapter on the "Steam-Engine." There, too, will be found the story of the scow that he built inland and ran down to the river's edge on rollers under its own steam power—the first American automobile.

For more than a hundred years after these early efforts of Cugnot, Murdock, and Evans, much time, money, and labor were expended in trying to perfect a practical, steam road vehicle. George Stephenson, Walter Hancock, Sir Goldsworthy Gurney, David Gordon, William Brinton, and others built various machines in England. Thomas Blanchard, in 1825, ran the first regular steam carriage in this country, at Springfield, Massachusetts. Like Evans, he could not induce anybody to finance him; he turned his efforts toward building steamboats. Other American inventors were Nathan Read, of Boston, and William T. James, J. K. Fisher, Richard Dudgeon, and John A. Reed, all of New York. John Reed's traction-engine was built in New York in 1858, and after being driven in the streets it was shipped by rail and river steamer to Nebraska City. Starting from there for Denver, it broke down after running seven miles.

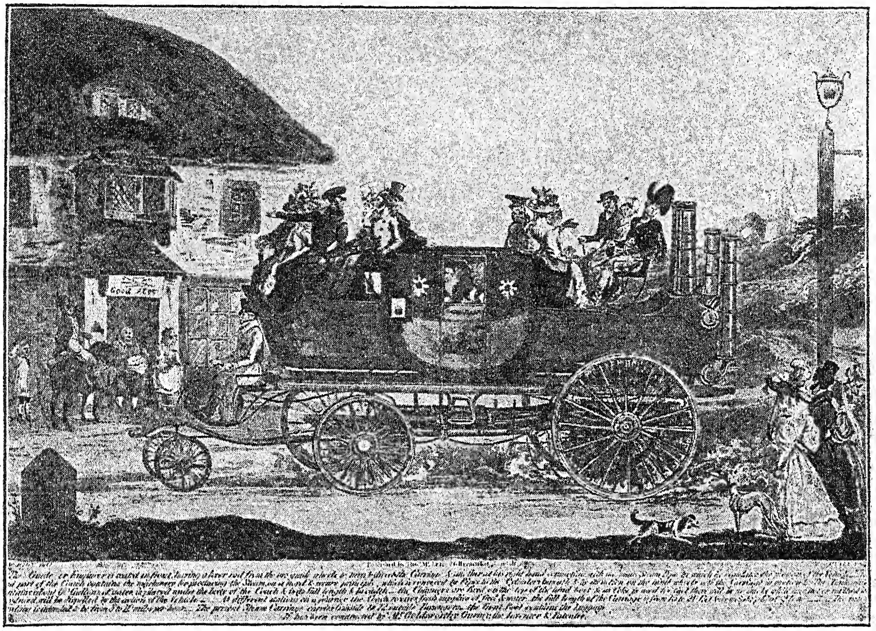
After the American Revolution more than a score of inventors in England and the United States were working on the perfection of a steam vehicle. By 1833, twenty steam coaches were travelling in and around London, and a dozen companies had been formed to build and operate them on stage routes.

The Road Locomotive Act of 1836

In those days the main roads, "turnpikes," were built by private companies that charged a fee for the privilege of using their highways. They also leased road rights to stage companies. The stage owners and drivers feared the steam coaches would rob them of business, and the farmers felt it would be impossible to sell horses to the stage companies at the old prices. The noisy "steamers" were ridiculed. Boys threw stones at them; farmers dug trenches across the roads to impede their clumsy progress.

The final, crushing blow came when the English Parliament

passed a law in 1836—the "Road Locomotive Act"—which imposed so high a tax on steam vehicles that their owners could not operate them profitably. Worst of all, the law required that a man carrying a red flag should walk ahead of a steam



GURNEY'S STEAM COACH.

Sir Goldsworthy Gurney began his work on steam carriages in 1823. In 1827 he patented this steam coach having six road wheels, the front pair, which the driver steered, being connected with the pole of an ordinary fore-carriage to control it; this peculiar steering arrangement is stated to have been so satisfactory that it could be worked by a child. The two steam cylinders were arranged on perches below the coach body and drove the rear wheels, which were loose on their axles, the connection to one or both being extremely ingenious. Superheated steam was supplied by a boiler placed in the hind boot. The draft was produced by a fan driven by a separate engine.

coach to warn people on the road! To-day we laugh at this odd English law. But it was no laughing matter in 1836, for it killed the automobile in England, just when it was beginning to win its way. Vicious as it was, that act remained in force for sixty years, restraining English engineers, while Frenchmen, Germans, and Americans forged ahead.

All the early inventors of the steam vehicle were hampered

by bad roads. In fact many engineers believed their inventions could never run successfully unless special tracks were laid for them. Wooden and iron tracks had been used in the English coal-mines from 1700 to 1800, making it easier for donkeys and horses to draw the coal-cars. Sometimes two or three cars were thus hauled by one animal.

But a few engineers believed that the highways should be so improved that tracks would be unnecessary. Among these James MacAdam, in Scotland, and Telford, in England, about 1800, invented ways of making roads with crushed stone. Their methods, afterward used for many years in Europe and America, made the road systems of England and France famous.

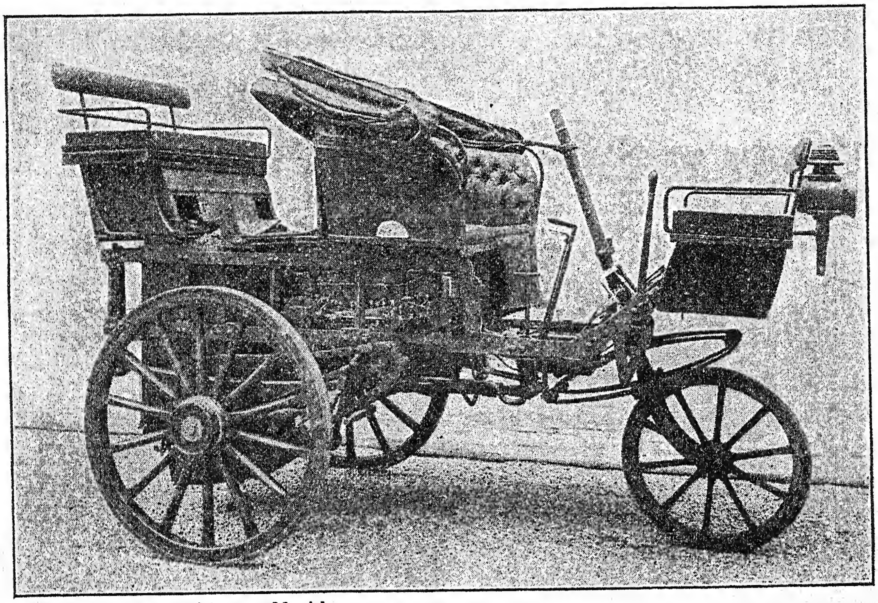
The Value of Petroleum

During the period when the English Government curbed her inventors by the Road Locomotive Act, two events of great importance concerning the rise of the automobile occurred in America. In Philadelphia was a Doctor Kier, who in 1850 discovered that when petroleum, or "coal-oil," as it was called, is heated the lighter parts are driven off—just as water turns to steam—and that the vapor can be cooled again into a light, refined oil. Thus he obtained kerosene, which he burned in lamps. The lightest vapor, gasoline, was allowed to waste, because it was explosive and dangerous. Now we can hardly obtain enough of it for the millions of automobiles in the world.

Nine years later, just two years before the Civil War, Colonel E. L. Drake drilled a well at Titusville, Pa., from which flowed 1,000 gallons of petroleum a day. The story is told in the chapter on oil. Many other wells were quickly sunk, and so began the great oil industry in this country. In 1860 some gasoline—the light, dangerous vapor—was offered for sale, but nobody knew just how it could be utilized. Indeed, it was twenty-five years before a way of using it in an engine was discovered.

The new liquid fuels—kerosene and, later, gasoline—contained much more energy per pound of weight than coal and were easier to use. They gave new hope to inventors of engines and motor vehicles. About 1870, certain men in France, Germany, and America began experimenting with the new fuel. Amedée

Bollée, of Le Mans, France, soon patented a light kerosene-burning steam carriage, and showed it in the exposition at Vienna, Austria, and in 1875 he ran one in and around Paris at a speed of nineteen miles an hour. Three years later he drove a steam carriage from Paris to Vienna. Bollée and his son



Courtesy of Deutsches Museum, Munich.

SERPOLLET STEAM TRICYCLE OF 1890.

L. Serpollet invented his flash boiler or instantaneous steam generator in 1887 and applied it soon after to a steam-driven tricycle. This was so successful that in 1888–9 he constructed first a larger tricycle and then some three-wheeled carriages, with a speed of about sixteen miles an hour.

continued making steam automobiles until early in the present century, then turning their attention to gasoline cars.

Another leading steam-car builder was Léon Serpollet, who brought out a three-wheel carriage twelve years after Bollée. It had a "flash" boiler, so called because when a little water was supplied to its highly heated tubes it flashed into steam. This principle (not the invention of Bollée, however) made it possible to raise steam very quickly and overcome a great fault of earlier machines. A rich American, F. L. Gardner, furnished money to help Serpollet carry out his work. Eventually Serpollet became the foremost steam-car manufacturer in Europe.

Light Steam Carriages Become Popular in America

America was not far behind. S. H. Roper, of Roxbury, Massachusetts, a mechanic, spent thirty years trying to perfect a steam-car. He was building steam bicycles and tricycles at the beginning of the Civil War, and kept on until he died, in 1894. With him begins the era of the light car in this country. He built a carriage in 1889 which he sold to a doctor, who used it for several years in his practice.

At the same time George E. Whitney, in Providence, Rhode Island; A. L. Riker, in Brooklyn, New York; and R. E. Olds, in Lansing, Michigan, were also making light steam-cars. Whitney patented his invention in 1896, and it ran so well that he sold the use of his patent rights to the Stanley brothers, who were making dry plates for cameras in Newton, Massachusetts, and to John Brisben Walker, who published the *Cosmopolitan Magazine* at Irvington-on-the-Hudson, New York, and founded the Mobile Company.

The Stanley brothers were twins with strange ways. They were Yankees and had much of the ingenuity we associate with Yankees. As might be expected, they improved on Whitney's design. Wrapping themselves and their plant in mystery they admitted few to their factory. Shrewd questioners were answered either brusquely or not at all. They never advertised, cared little about building up a business as we do to-day, and yet they sold an increasing number of steam-cars each year. After they had flourished under the Whitney patent they sold their rights to Amzi L. Barber, a wealthy match manufacturer.

Later the Stanleys decided to resume steam-car building. Unable to use the Whitney design with the engine under the seat, they placed it horizontally on the rear axle. One of the brothers was killed in an automobile accident some years ago, but the other is still at the head of the company bearing the Stanley name. It is one of the very few companies still making steam-cars in this country.

John Brisben Walker, who founded the Mobile Company of America, built a huge factory at Tarrytown and for a few years made and sold thousands of steam Mobiles.

Armed with the Whitney patent, Amzi L. Barber, in 1899, founded the Locomobile Company of America. He started manufacturing in Newton, Massachusetts, but moved to a larger plant in Bridgeport. There he developed a big business. Great sums of money were spent in advertising his Locomobiles, and many thousands were sold, not only in the United States, but in all parts of the world. Upward of 500 were built in 1899 and more than 1,000 the next year. Barber was the first man to put into practice cheap production and low selling price—the idea that Henry Ford was so brilliantly to apply later on.

The Bicycle Craze

We must go back now and note another factor that greatly influenced the manufacture of these early light steam-cars, the bicycle. The bicycle goes back to 1800, but "wheels" were not introduced generally until Colonel Albert A. Pope patented the first safety bicycle and began manufacturing it in Hartford, Connecticut, about 1886. His first bicycles weighed more than 100 pounds and, of course, were hard to pedal. Pope and other bicycle-makers then tried in every way to reduce the weight and make the machines easier to run. They put ball bearings in the wheels and crank-shaft brackets, made frames of thin drawn-steel tubing, and adopted wood rims and fine-tension steel spokes. In ten years the weight of the bicycle was reduced to about twenty-five pounds; that of the racing-machine to fifteen pounds; and prices were gradually reduced from $150 to $50. By 1896 there were about 4,000,000 riders in this country. The making of bicycles became a remarkable industry. There were more than 250 bicycle companies in the United States, with over $60,000,000 invested.

Such was the demand for bicycles that ways had to be found to produce them faster and in larger numbers. To meet this, special machinery was invented to turn out parts of the same kind. Indeed, some companies manufactured only parts, such as spokes, rims, pedals, bearings, tires, saddles, and handle-bars.

Americans, therefore, in the days of the bicycle, learned how to build light vehicles and make parts both rapidly and cheaply. Moreover, the bicycle created a demand for better steel and

bearings. When in 1896 the bicycle began to lose its popularity, bicycle manufacturers cast about for something to take its place. Naturally they turned to the steam-car, then beginning to attract attention. They had money to engage in experimental work; they also had experience.

This helps to explain why the early automobiles, particularly the steam-cars of the Stanleys, John Brisben Walker, and the Locomobile Company, had so much in common with the bicycle. Their frames were of steel tubing; they had ball bearings; their wheels had wire spokes and pneumatic tires, and the whole machine was extremely light.

The First Gasoline Automobiles

Gasoline automobiles attracted very little attention up to the beginning of the present century. A few men were hard at work fifteen and twenty years before they succeeded in perfecting a light, powerful engine that would use the great energy in liquid fuels without the loss caused by converting water into steam. They saw that if they could use the fuel directly in the engine they would get more power from it, and that it would not be necessary to stop every few miles to take on more water, which quickly boiled away.

In 1799 a French mechanic named LeBon had invented an engine that worked on the principle of a cannon. The cylinder was similar to the barrel of a gun and the piston like a cannon-ball. Instead of gunpowder, he exploded street-lighting gas in the cylinder behind the piston. The force drove the piston toward the open end of the cylinder, and it was fastened so that it was not completely driven out, but had to return. When it had gone as far as it could, the burned gas was let out, and a new charge admitted. The same principle is used in all automobile engines to-day. For that reason they are known as "explosion" engines, because the gasoline, when mixed with the right amount of air, forms a gas that is exploded in the cylinders, just as powder is exploded in a gun.

LeBon's method of using an electric spark to ignite the gas in his engine was also used in 1860 by another Frenchman, Jean Joseph Lénoir. The latter built a one and one-half horse-power

gas-engine of the LeBon type, and put it in a road vehicle. Probably the machine did not run very well, because he turned from automobiles to the making of boats. However, he was luckier than most inventors, for the Academy of Sciences gave him a decoration in honor of his work, and the Society of Encouragement awarded him the Grand Prize of Argenteuil, about $2,400.

In Cologne, Germany, Doctor N. A. Otto also began building gas-engines, and in the course of fifteen or twenty years built up a great business in making what is known as the Otto engine. He first used street gas, and later gasoline. In 1876 he invented an engine in which the gas is compressed before it is exploded; the principle which had been suggested by William Barnett in 1838. Compression is all important, and to Otto belongs the credit of having practically succeeded in compressing gas.

An engine in which gas is compressed is very powerful for its size and weight. The piston does not have to travel very far at each stroke, because the cylinder need not be long and because the engine can run very fast. The faster a gas-engine runs the more power does it generate and the lighter can it be made. In some automobile engines the crank-shaft and fly-wheel turn around as fast as 2,000 times a minute, or more than 30 times a second.

Doctor Otto gave us what is called the "four-cycle engine," the type used in all automobiles. The reason for the name becomes apparent when the method of its operation is considered. Four distinct processes occur.

In the first place the piston moves away from the cylinder head. As it does so a mixture of gasoline vapor is drawn in through the mechanically opened inlet-valves, a mixture consisting of just the right amount of gasoline vapor and air. This sucking in of the mixture is known as the first cycle. The inlet-valves close and the piston now travels back, compressing the mixture as it does so. This is the second cycle. At the end of this compression stroke of the piston the electric spark is made to pass and ignite the mixture. A violent explosion occurs by which the piston is again driven out. This is the third cycle. Once more the piston returns. The exhaust-valves are opened

mechanically, and the piston discharges through them the spent gases of the explosion. This is the fourth cycle. The piston again moves forward, now drawing in a fresh supply of mixed air and gasoline vapor, and thus recommences the first cycle. And so the second cycle (compression), the third cycle (explosion), and the fourth cycle (exhaustion) are repeated. This repetition of the cycles occurs nearly 1,000 times a minute.

It should be noticed that of these four piston strokes only the third, or the explosion stroke, does really useful work, for it is the explosion that drives the engine. The other strokes are concerned only with preparing the engine for an explosion.

Naturally the piston must be kept moving during the three powerless strokes. It is the function of the fly-wheel to keep it in motion. The fly-wheel turns with the crank-shaft. It is so heavy that once it is set in motion its momentum will keep it moving for a time. So it is the momentum of the fly-wheel that moves the piston back after explosion, then forward during the first cycle, and backward during the second cycle.

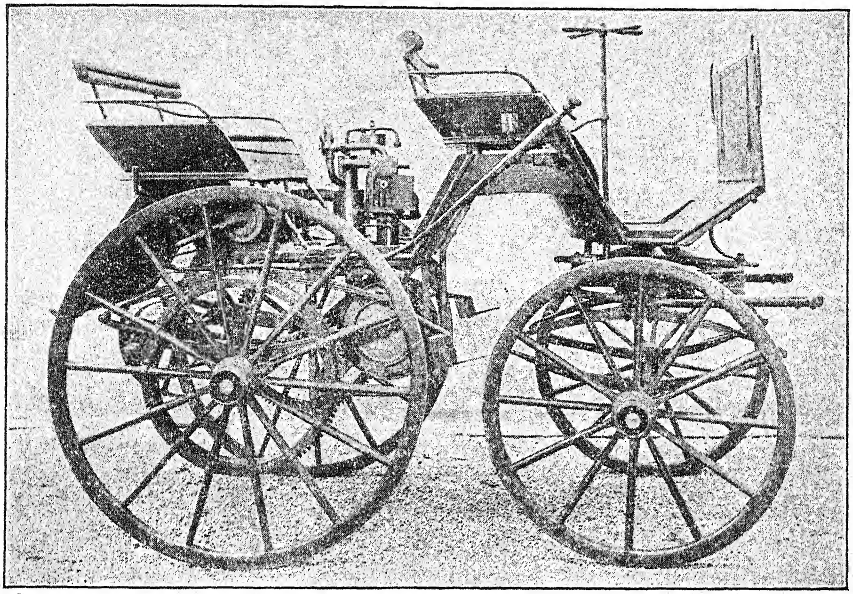
The crank-shaft drives the rear wheels of the automobile either with the aid of chains, as in the earlier cars, or shaft and bevel gears, as in modern cars.

Daimler and the Modern Automobile

The Otto Engine Works made a great many gas-engines for stationary work, but they did not produce portable engines for use in road vehicles. During the ten years from 1872 to 1882 they employed a man who, later, did more than any other inventor to perfect the gasoline motor-car. His name was Gottlieb Daimler, of Württemburg. Daimler received an engineering education in the Polytechnic School in Stuttgart, after which he spent two years in practical work at the Karlsruhe Machine Works and the machine-shops of England. When he was fifty years old he left the Otto Works and started a shop of his own at Cannstatt, where he could give all his time to improving light gasoline-engines for automobiles and constructing motor-cars. Here he built the wonderful Mercedes automobile, naming it after his daughter. In later years he made other improved automobiles which, exported to different countries, won many

great speed contests. Some of the Mercedes' chassis sold for $20,000 or more each, without bodies.

Daimler built a motor-bicycle in 1885, then he made a tricycle, and finally four-wheeled machines. He adopted the Otto principle, making jackets or covers in which cooling water



Courtesy of Deutsches Museum, Munich.

DAIMLER'S AUTOMOBILE OF THE LATE EIGHTIES.

The modern motor-car was rendered possible mainly by the invention, in 1884, by Gottlieb Daimler, of the light high-speed gasoline-engine. This engine, in the form patented by Daimler in 1889, was taken up by Panhard and Levassor, who applied it to road carriages and developed a successful design.

circulated around the cylinder-heads in his engines. His chief engineer, Wilhelm Maybach, added many important improvements that made the Mercedes cars, for a time, the finest in the world.

The Daimler Works also produced the aspirating carburetor, in which the suction of the engine draws a current of air through the carburetor, and with it a fine jet of gasoline, thus producing a proper explosive mixture. Daimler and Maybach adopted the cone-clutch and designed a suitable sliding gear change-speed mechanism that allowed the engine to run at a nearly

uniform and efficient rate, permitting the speed of the car to be varied as conditions required. The Daimler works were the first to adopt the V-type engine, now used in American eight-cylinder and twelve-cylinder cars. It is called the V-type because the cylinders are set in two rows at an angle to each other.

There was another German, Carl Benz, of Karlsruhe, who was working hard on the gasoline-automobile problem, and who subsequently disputed with Daimler the claim to be the inventor of the modern automobile. He had spent four years at the Technical High School in his town and then had three years of shop experience in the Karlsruhe Machine Works, where Daimler had also worked. When only twenty-eight Benz opened his own shop in Mannheim, and began making stationary gas-engines in 1880. Four years later he turned out his first gasoline automobile, which he ran in Mannheim the following year. This machine, which had a leather-belt drive, was patented in January, 1886. It is said the patent was the first granted in Germany for a light, oil-fuel motor vehicle, and although issued thirty-five years ago it covers some of the most important features of present-day automobiles, such as the Otto four-cycle principle, water-jacketed cylinders, and electric ignition.

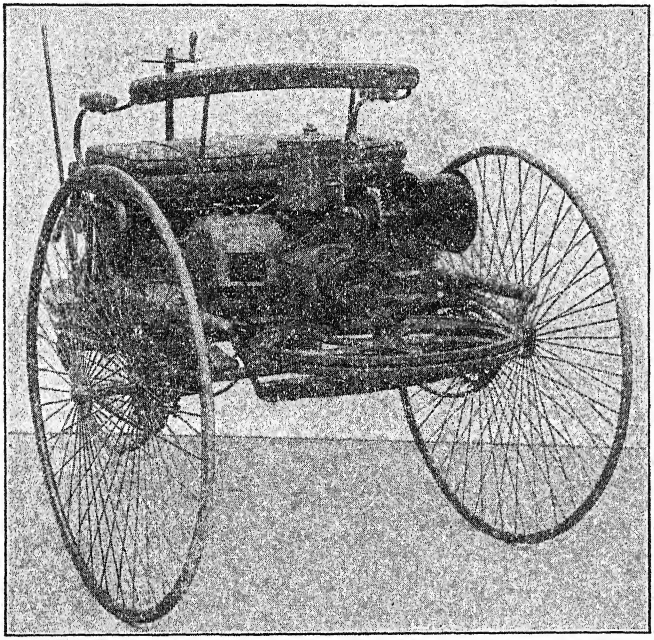
The first automobile imported into the United States was a Benz. It was displayed at the World's Fair or Columbian Exposition in Chicago, in 1893. A Benz also took part in the road race from Chicago to Waukegan and return in November, 1895; the race was won, however, by the Duryea motor-buggy.

Levassor Sees Advantages in Daimler's System

Although the two Germans—Benz and Daimler—were the first men to make successful gasoline automobiles, progress in the art of building motor-cars was made by the Frenchman, Levassor, who graduated from the Central School of Arts and Manufactures in Paris, then worked for eight years as an engineer in manufacturing plants in Belgium and France, and finally became junior partner in the firm of Perrin and Panhard. One cannot but be impressed with the careers of such men as Levassor, Daimler, and Benz, all of whom followed up an engineering education by practical work in machine and engine works. Levassor had long been interested in gas-engines and

made his first in France according to the Otto system. Then, in 1886, he secured French rights to use the Daimler patents, and in a few years brought out the first Panhard-Levassor automobile.

Other French experimenters obtained rights from Daimler and Benz about the same time, and they used the Daimler and



Courtesy of Deutsches Museum, Munich.

BENZ AUTOMOBILE OF 1885.

The car was a two-seated, three-wheeled vehicle with wire wheels and solid rubber tires. The engine was placed over the rear driving-axle and had a single horizontal cylinder with a vertical crank-shaft carrying a large fly-wheel. The car was rated at about 0.75 horse-power.

Benz engines in bicycles, tricycles, and four-wheeled road vehicles. But the Panhard-Levassor patents are notable because they cover the arrangement of all the necessary parts of the motor-car just as they appear in the automobiles of to-day.

Panhard and Levassor were the first to patent and construct cars with frames made separately from the body and secured to the axles by elliptical springs, the engine and change-speed gearing being mounted on this frame. The advantage of this was obvious. Because of the springs between the axles and the

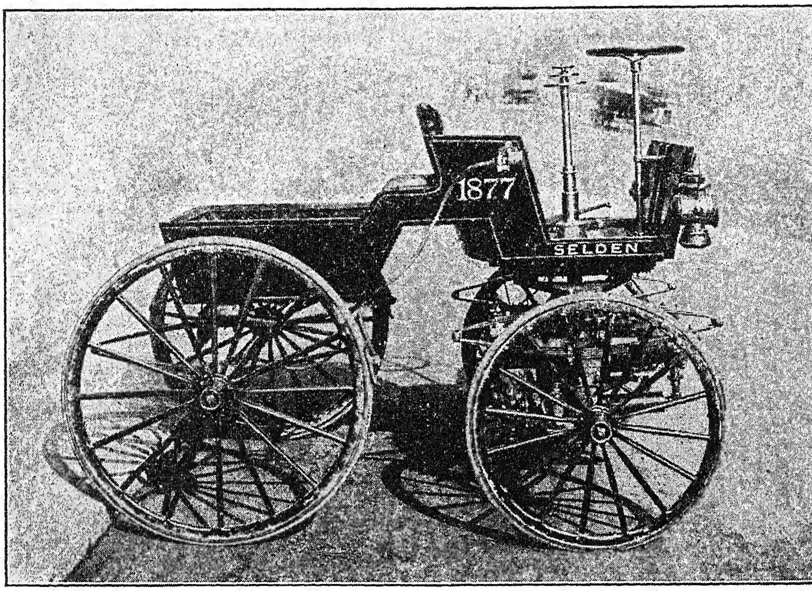
heavy machinery, jolting over the roads did not injure the machinery or break the axles and wheels. To Levassor also goes the honor of being the first to place the engine at the front, under a hood, and the radiator in front of the engine, where it would get the full cooling effect of the air current created as the car moved forward. Panhard and Levassor set the engine upright or vertical, used a cone-shaped clutch that engaged the fly-wheel, connected the cone to a set of gears in a box under the middle of the car, and used differential gears in a cross shaft with two driving chains from the ends of this shaft to sprockets on the rear wheels. The main difference between this arrangement and modern cars is that instead of using chains we now use a single lengthwise shaft to drive the rear wheels and place the differential gears in the rear axle.

In Europe and America, toward the end of the nineteenth century, many automobiles were made with different types of gasoline-engines and other arrangements of the various parts of the mechanism; but in time the whole world came back to the Panhard-Levassor principle. The first automobile trial run—in July, 1894, from Paris to Rouen, a distance of eighty miles—was won by Panhard-Levassor and Peugeot cars, four of each, driven by Daimler type engines of three and one-half horsepower. These eight cars were so nearly tied for the best positions at the finish of the trial that the manufacturers divided the prize.

Selden and His American Patents

America was only a little behind Europe in building and successfully running gasoline machines. The first man to design and begin building a gasoline carriage applied for a patent in the United States in 1879, about seven years before Benz and Daimler patented their ideas in Germany. He was George B. Selden, of Rochester, New York, a patent lawyer and an inventor. After leaving school he entered Yale University to pursue classical studies; but his father was taken ill during a visit to Switzerland, and the son left college in order to reach his bedside. Returning to America, Selden entered the Sheffield Scientific School of Yale University, and after graduation completed a law course and was admitted to the bar in 1871.

The idea of an automobile flashed on him when he saw a steam road-roller. After much study he decided that steam was not the best power for light carriages. In a shop for experimental work that he had fitted up at home, he built a gasoline-engine in 1877, and made drawings of a carriage to be driven by a three-cylinder engine mounted crosswise on the front axle.



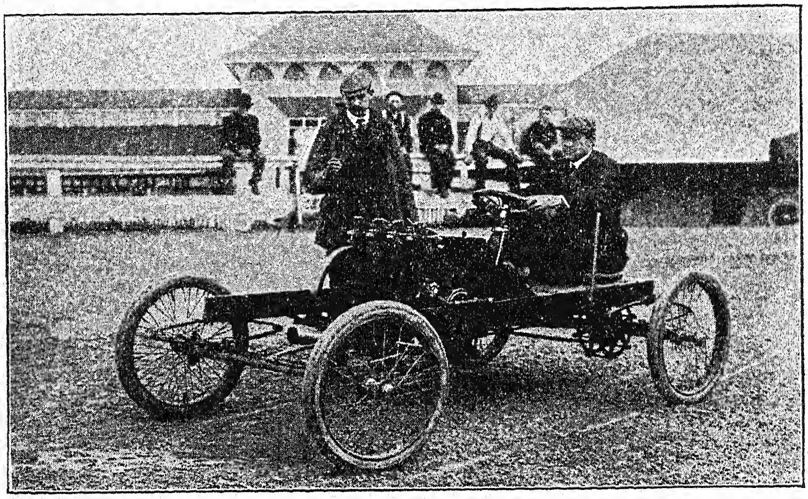
REPLICA OF SELDEN CAR (1877).

This car was built to demonstrate the operativeness of the Selden automobile in a patent-infringement suit.

Selden tried many times to get rich men to invest in the manufacture of his "horseless carriage." He even went to Europe for that purpose after having been rebuffed in this country. For fifteen years he strove to raise the necessary money, and during that time he kept his application alive in the Patent Office by skilful juggling, so that, after it was granted, he would still have seventeen years in which to make and sell gasoline road vehicles.

His patent, as finally issued in 1895, covered the principle of using an explosion engine in a road vehicle. Had Selden been

able to build automobiles while other Americans and Europeans were developing their ideas, he might have monopolized the whole industry. Half a dozen times, when he was just on the point of making an agreement with some man or group of men with money, something happened to prevent his coming to terms. One man died suddenly, another failed in business and



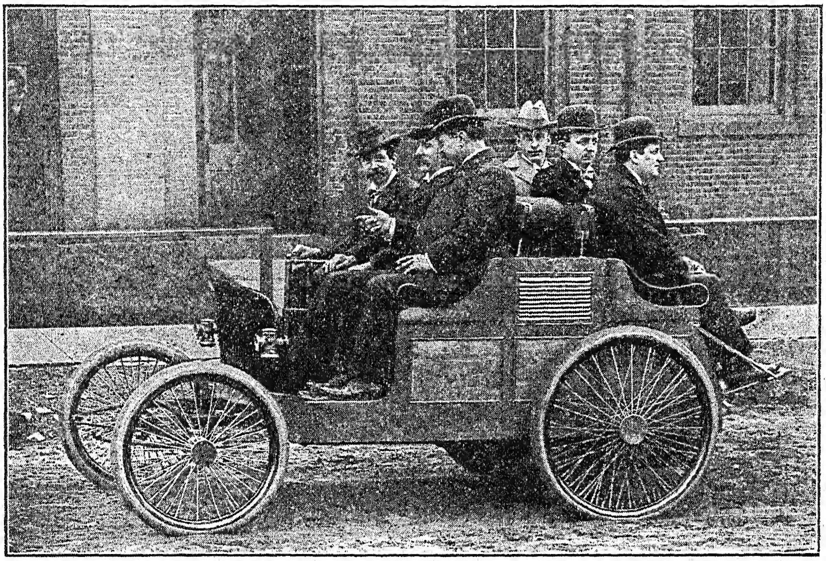
FRANKLIN CAR OF 1903.

John Williamson, designer of Franklin car, at wheel of 10 horse-power Franklin, with which he won a 5-mile race at Yonkers, N. Y., July 25, 1903, in 6 minutes, $54\frac{3}{5}$ seconds.

lost his money, and the rest either became sick, had accidents, or changed their minds.

During this period other men in America prospered in the automobile business, many of them making money under licenses to use the Selden patent. In 1902 and 1903, suits were brought under his patent against Alexander Winton, Henry Ford, and others. Winton soon agreed to pay a license and joined the Association of Licensed Automobile Manufacturers which, controlling the licenses under Selden's patent, was formed about that time. Ford fought the case, and it was carried from one court to another until a final decision was reached in the Court of Appeals in 1911. This court decided that Selden's patent was good and the first of its kind; but they also found that

other manufacturers did not infringe it because they were using Otto engines, whereas Selden had limited himself to the use of another type of engine. It was brought out in the suit that more than $2,000,000 had been paid in royalties to the Associa-



DOS-A-DOS AUTOMOBILE OF THE EARLY NINETIES.

This is Winton's second experimental model, a frank imitation of contemporary French automobile designs.

tion of Licensed Automobile Manufacturers. Selden is said to have received about $200,000 as his share of the royalties.

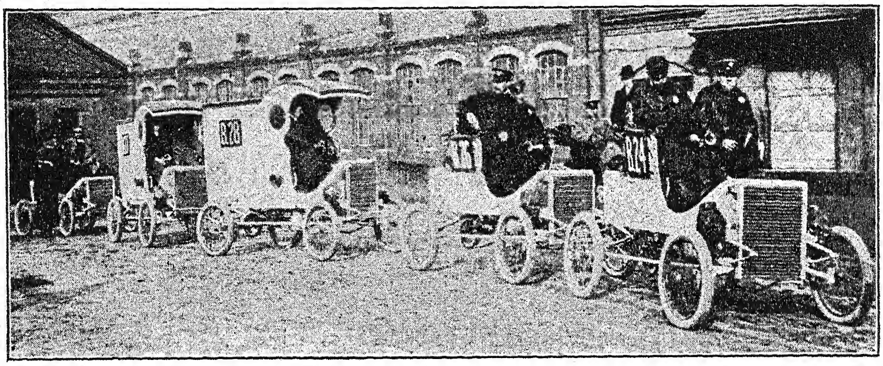
Rise and Decline of the Electric Vehicle

William Morrison, of Des Moines, Iowa, was the first to design and build an electric road vehicle. That was in the summer of 1891. He sold it the next year to J. B. McDonald, president of the American Battery Company, of Chicago. It created great curiosity in the streets of that city, and the owner sometimes had to ask the police to make the crowds of people move on, so that he could start his machine.

A year after Morrison brought out his first machine, Fiske Warren, of Boston, made an electric vehicle called a "brake"

which could carry eight passengers at a speed of sixteen miles an hour for fifty miles on one battery charge. About the same time, Morris and Salom, of Philadelphia, began making electric vehicles, but later sold out to the Electric Vehicle Company.

C. E. Woods, of Chicago, and A. L. Riker, of Brooklyn, started making electric automobiles in 1893. A few years later the Waverley Company, bicycle manufacturers in Indianapolis,



WHITE STEAM-CARS THAT COMPETED IN THE NEW YORK-BOSTON 500-MILE ENDURANCE RUN, 1902.

and the Bakers, in Cleveland, went into the business. The Bakers were first to build very light, two-passenger electric runabouts.

Pope, Riker, Waverley, and Barrows electric vehicles were exhibited in 1898 at the electrical show in Madison Square Garden, New York, and again at the bicycle show the following year. The first real automobile show in this country was held in New York in 1900. More than one-third of the space was taken up by electric vehicles; the rest chiefly by steam-cars.

William C. Whitney, secretary of the navy under President Cleveland, became interested in electric railways and secured the control of the Selden patent in 1899. He had just bought the automobile business from the Pope Manufacturing Company, which turned from making bicycles to manufacturing electric vehicles. At that time electric vehicles were beginning to compete for public favor with light steam-cars and were more numerous than gasoline cars. With several other

street-railway capitalists, Whitney organized the leading electric-vehicle companies into a group and formed companies in New York, Boston, Philadelphia, Chicago, and other large cities to operate public electric cabs. All were controlled by the Electric Vehicle Company, which company also secured the right to make gasoline automobiles under Selden's patent through Whitney's purchase of the Pope business.

Duryea and His Gasoline Buggies

The honor of being first to make a successful gasoline automobile in America belongs to Charles E. Duryea. When he was about twenty-five or thirty years old he saw a stationary gasoline-engine with electric ignition, and made up his mind that such an engine could be used to run a buggy. He began to study and experiment, and in 1891, with the help of his brother, J. Frank Duryea, made drawings and started to build a gasoline carriage. They took almost a year to complete their first motor carriage, which, in the end, failed to satisfy them. So they kept on making and improving, and finished their fifth buggy in 1894. This one had most of the main features of modern automobiles, such as a four-cylinder engine with water-jackets, electric ignition, bevel-gear differential, rigid front axle with steering knuckles at the ends, and pneumatic tires. It was the first machine in America to be fitted with such tires.

The Duryeas were very capable young mechanics, and this motor carriage was so well made that it won the first American road race. It was run in the snow on Thanksgiving Day from Chicago to Waukegan for a money prize offered by the Chicago *Times-Herald*. The average speed made by the winning car was ten miles an hour. Most of the contestants failed to finish.

The following year the brothers built thirteen more gasoline motor carriages; the first that were regularly manufactured for sale in this country. They entered four in the race from New York to Irvington for the *Cosmopolitan* prize offered by John Brisben Walker, who shortly after became interested in the light steam carriage, and founded the Mobile Company. Three of the Duryea machines were the only ones to finish the run the

same day, which shows how crude and unreliable the automobiles of those days were; the whole distance being no more than fifty miles.

Duryea First in Race from London to Brighton

The Duryeas then took two of their machines to England and entered them in the first automobile contest in that country; a race from London to Brighton. To the great amazement of the English and French spectators, one of the Duryea cars finished the fifty-two-mile course more than an hour ahead of French machines which had won races in France earlier in the year.

If Charles Duryea, in later years, had been willing to adopt the construction and arrangement of parts designed by Levassor and preferred by the public, he might have become one of the leading manufacturers of the world. But having proved that his machine was faster and more dependable than others made up to that time he persisted in mounting the engine in the rear of the body and continued to provide a handle or tiller for steering and controlling the speed. Despite the trend of the mechanical times, he refused to build what the public wanted. He organized several companies and made different styles of motor-cars but never achieved success in business.

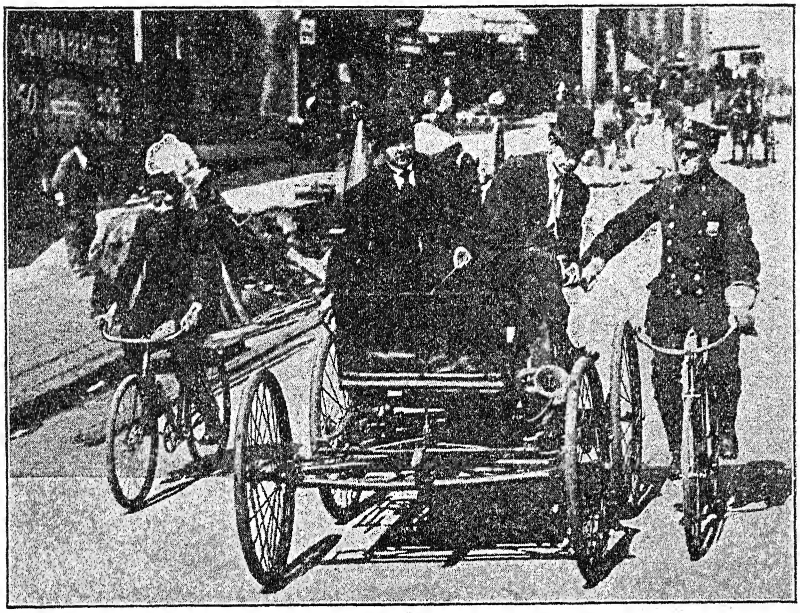
Other Gasoline Cars of Thirty Years Ago

While Duryea was working on his first machine, Elwood Haynes, a scientific worker in metals and a machinist in Kokomo, Ind., Henry Ford, a farmer's son and mechanic in Detroit, R. E. Olds, in Lansing, Michigan, and Alexander Winton, a bicycle repairman in Cleveland, Ohio, were all trying to make bicycles or carriages that could be driven by small engines. Haynes was fortunate in securing the aid of the Apperson brothers, who had a machine-shop. Permitting Haynes to experiment in their shop, they helped him with money, and when he had finished his car staked the good standing of their firm's name by calling it the Haynes-Apperson.

This first Haynes-Apperson was finished the same year that Duryea's third experimental carriage was successfully tested.

Ford, too, in the spring of that year made his first successful automobile. It was a close race, but Duryea was the first to bring his machines to public notice.

Although Olds made a three-wheel steam vehicle in 1887 he did not bring out his gasoline car until about 1900. He then



HAYNES GASOLINE CAR OF 1895.

Elwood Haynes drove his first car, his own invention, in Chicago in 1895. He was stopped by a policeman and told to get his "horseless carriage" off the street.

put on the market a little one-cylinder, two-passenger runabout, with a curved dash like the dashboard of a sleigh and a tiller for steering. It was the first cheap, American gasoline automobile, and sold for $650. It had speed, ran easily and quietly, and soon became so popular that, for those days, it was manufactured in large numbers.

After selling out, Olds started a new company in Lansing to make the Reo cars and trucks; the name being formed by his own initials. As head of the Olds company he had trained a number of bright young men who, later, organized automobile companies of their own. One was J. D. Maxwell, who de-

signed and manufactured the Maxwell-Briscoe cars at Tarrytown in the factory of the old Mobile Company. Roy D. Chapin and Howard E. Coffin, two other pupils, became interested in the E. R. Thomas Motor Company, of Buffalo, brought about its removal to Detroit, later reorganized it as the Chalmers Motor Car Company, and finally left the company to form the Hudson Motor Car Company.

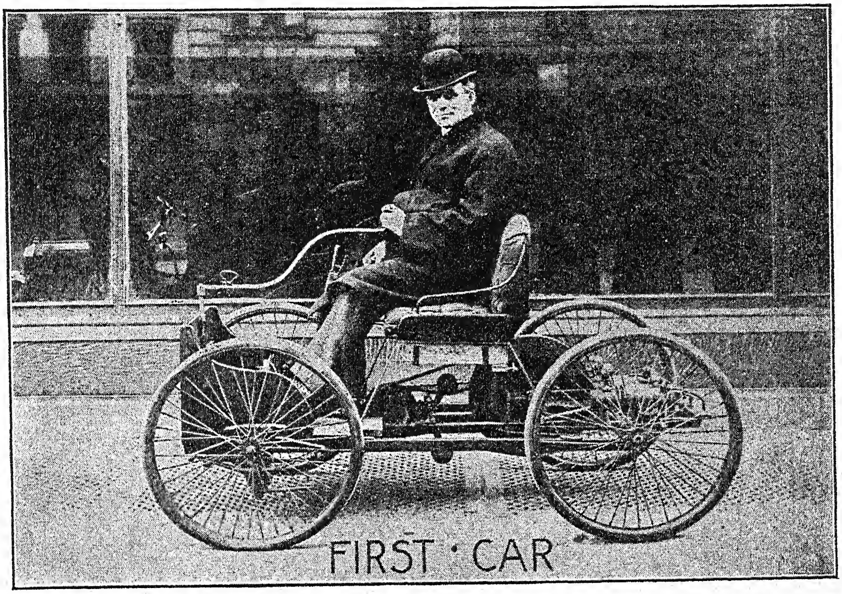
Ford's Rise from Farmer Boy to Multimillionaire

Henry Ford has produced about as many motor-cars as all the other American manufacturers together. In the short space of only fifteen years he rose from poverty to such wealth that he is now rated as one of the richest men in the world.

Ford's great success is due to a combination of unusual qualities. He had a strong leaning toward mechanics, and early in his career became a firm believer in the policy of low prices, large sales, and small profits. If he had taken up watch-making—as he was inclined to do when a boy—he would have made dollar watches. If he had been a merchant instead of an engineer, he would have opened five-and-ten-cent stores throughout the country. As it was, he outstripped other automobile-makers by designing a strong, light, fast gasoline car to sell at a low price, and then confining himself to the improvement of the same model year after year.

When an article is manufactured in enormous numbers, any general change in design costs a fortune and causes delay in production. New drawings must be made, new patterns and moulds are wanted for new castings, new dies for forging machines, even new manufacturing machinery must often be installed. Such changes involve an enormous expenditure, which naturally increases the selling price of the product. Ford realized this and avoided it. When he finally produced a model that proved satisfactory and found that people were eager to take advantage of his low price, he increased the size and output of his factory year after year until he was able to build and assemble 6,000 cars a day! He now has such a huge market and can make cars so cheaply that nobody can compete with him.

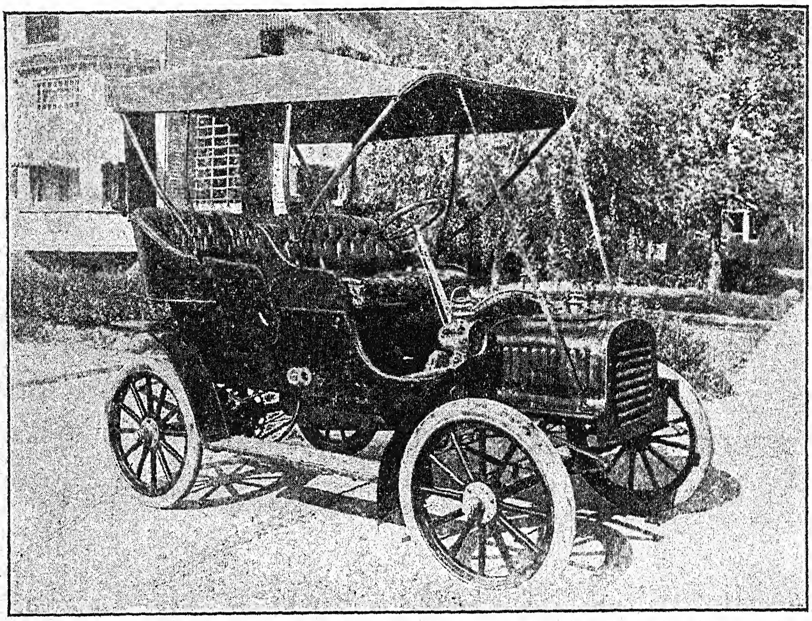
Henry Ford's father, a hard-working farmer who came to this country from Ireland in 1847, was barely able to give his son a grammar-school education. He wanted him to be a farmer and raise potatoes, apples, and peaches, and he objected to his wasting time in the little machine-shop he had fitted up



HENRY FORD IN HIS FIRST CAR.

on the farm. Even after Ford went to Detroit and worked for several years as machinist, steam engineer, skilled shipyard mechanic, and an expert at installing engines and machinery for George Westinghouse and Company, his father tried to induce him to return to farming by offering him forty acres of timber-land. The son, then about twenty-four, accepted the gift, set up a sawmill, sold the timber, and used the money to fit up a shop on the land. There, in 1887, he started to make a little steam automobile. After two years, his money gave out and he went back to Detroit and earned his living as chief engineer of the Detroit Edison Illuminating Company, a position he held for seven years. Following a hard day in the power-house, he would go to his little shop and work on a new kind of auto-

mobile until late at night. Not long after the appearance of Duryea's motor carriage, Ford finally finished his first gasoline machine and, in 1893, tested it on the road. To the surprise of every one, his funny little car actually ran from twenty-five to



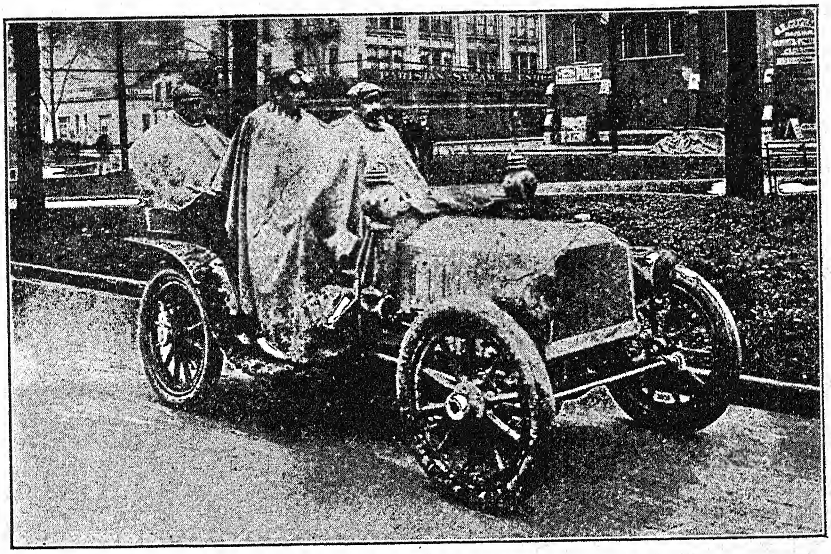
ONE OF FORD'S EARLY MODELS, THE FORERUNNER OF THE PRESENT MODEL.

thirty miles an hour! It was driven by a twin-cylinder, four-cycle, water-cooled engine.

Five years later, after building a second and better car, he formed the Detroit Automobile Company, with an authorized capital stock of $50,000, of which he owned one-sixth. He was employed as chief engineer at $100 a month. The company, however, was not a success. Ford left it in 1901 and started again in a machine-shop near by. Leland and Faulkener, a firm of fine-machinery builders in Detroit, bought the plant and began making Cadillac automobiles.

Ford's next venture was the Ford Motor Company, formed with $100,000 capital stock, of which he owned one-quarter.

This company made the first Ford car of the present type in 1903. It has grown rapidly, until now it is the largest automobile company in the world, employing 50,000 men. Ford had perfect confidence in the future of the business and personally managed to secure $175,000 with which he bought another quarter of the stock, thereby obtaining control. In order to



TYPICAL PACKARD FOUR-CYLINDER CAR OF ABOUT 1904.

There was no body in the modern sense, no windshield, no protection for driver and passengers.

get the best possible men to work with him, he gave an interest in the business to James Couzens—later elected mayor of Detroit—and to Horace and John Dodge, eventually the organizers of the Dodge Brothers Motor Car Company. These men shared in the building up of the company, and also in its huge profits, Ford afterward buying back their stock at an enormous price.

Ford, a close buyer of materials and parts, sought in every way to hold the producing and selling costs of his cars at the lowest possible figure, so that the retail price would be low. It is said that years ago, when some fine gold stripes or lines

were painted on the bodies to relieve the solid-black finish, the foreman of the striping-room went to Ford and demanded higher wages on behalf of the men who did the striping. Ford thought a moment, then asked: "How much does it cost to put the stripes on?" The foreman told him. "Then," said Ford, "we will do without the stripes." And he discharged all of the stripers.

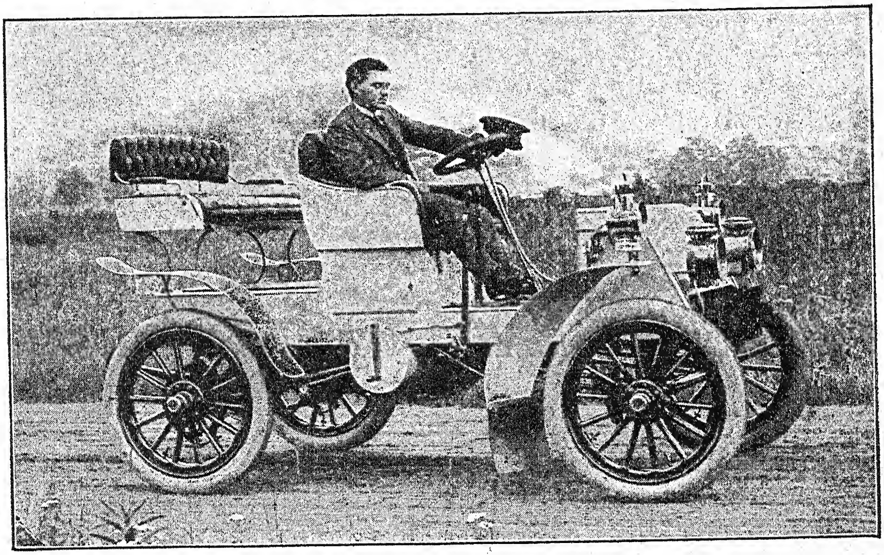
How America Became the Leading Automobile Country

The leadership of American automobile manufacture was made possible only because our vast country has great natural resources in its rich farm land, its forests, and its minerals. The ease with which farm products and raw materials were converted into wealth attracted many immigrants from Europe; the population increased so rapidly that there are now more than 110,000,000 people in the United States. Here, in a country where progress and opportunity run hand in hand, a man received higher wages or made more money than elsewhere. When automobiles were placed on the market he was able to purchase and own one for himself. To-day, one in every seven Americans is the proud possessor of an automobile; in fact there are about seven times as many automobiles and motor-trucks in use in the United States as in the rest of the world!

Such was the growing wealth of America that our manufacturers were able to sell automobiles as soon as they learned the secret of successfully making them. With enough orders assured, they began to use automatic machinery to produce the different parts rapidly in quantity; just as they had done during the bicycle craze. Instead of casting and boring the four or six cylinders of an engine separately, they cast them in one block, and then bored all of them simultaneously in one boring-machine. The drilling of one bolt-hole at a time was superseded by multiple drill-presses, which drilled a dozen or more holes at once. And so with every part. Frames are now formed in huge hydraulic presses that shape a whole side member out of steel in one operation; axles are forged in one piece in powerful forging machines that cost upward of $100,000; gears are cut, shaped, and ground from long bars, in automatic ma-

chines. Abroad, the old method of making parts singly is still in use in some plants.

In Europe every part of an automobile is usually made to fit the other parts of the same car nicely. In this country all the parts are duplicated, so that in assembling an automobile, it does not matter what cylinder casting, piston, valve, gear, or other part is picked out of a pile. It was Eli Whitney who in-



PACKARD AUTOMOBILE OF THE EARLY NINETIES.

It took automobile designers time to forget that their cars were more than "horseless carriages." Even in this early Packard model the general design still suggests the horse-drawn type of vehicle.

vented the principle of interchangeable parts; the story of that great idea is told in another chapter on machine tools in this book. Interchangeability made it possible to assemble engines, transmissions, axles, and, finally, the whole car, rapidly.

Let us see what this means. In 1912 it took fourteen man-hours to assemble one Ford car; that is, it required the equivalent of fourteen hours' labor by one man or seven hours' work by two men. The cost was \$8.75. Two years later the average time for assembling had been reduced to two man-hours, and the cost to \$1.25! The machining of a whole cylinder-

block, boring and grinding the inside, drilling bolt-holes, grinding valve-seats, planing off the base and head—twenty-eight separate operations—took only forty-five minutes.

The Beginning of Big Production of Cheap Cars

It was Walter E. Flanders, an Ohio machinist, who showed American manufacturers the way to produce cars rapidly in large numbers. In the early days of the Ford Company he sent in his card to Mr. Ford, who at that time found it hard to secure crank-shafts rapidly enough. Flanders took an order for 1,000 and succeeded in delivering them on time. Some time later, when Ford wanted to turn out 10,000 cars in a year, he hired Flanders as production manager. Flanders immediately stopped operations in the plant, rearranged the various departments and machinery, and informed all the companies from whom materials, parts, and accessories were ordered just what was expected of them. He then started to make as many parts as he could, bought the rest, and began to assemble cars. Every man was driven at top speed. Cars were put together faster than had ever been possible before, and the last of the 10,000 was finished two days before the end of the year. Flanders did not stay with the Ford Company, but started a company of his own.

"Progressive Assembling" in the Automobile Factory

When factories began to make automobiles by tens of thousands a year, it became a problem how to put them together fast enough in the smallest possible factory space. Ford and other makers of low and medium-priced machines adopted what is now called "progressive assembling." They installed moving chainways or conveyers, which carried the cars to different groups of machinists. They arranged the stock-rooms for the different parts or "units" around the assembling-room and built tracks or overhead carriers to bring the units to the gangs of workmen.

Rear axles, with the differential gearing and driving-shafts all in place, are brought from the axle stock-room to the head of the assembling track. The first working crew place them on the chain or track, one after another at proper intervals. As

the track slowly moves these along, the next crew fits front axles; a third crew, the frames on the axles; a fourth crew bolts the frames to the springs; a fifth sets and bolts the engines in the frame; a sixth mounts the steering-gear and column; a seventh the transmission or change-speed-gear; other crews connect and adjust pedals, brakes, and so on. As the chassis nears the end of the track, the wheels are slipped on and adjusted. When the completed car reaches the end of the track it receives a little gasoline. A man jumps into the seat and makes a brief test of the car, whereupon it runs to the loading platform and into a waiting freight-car for shipment.

In this process of "progressive assembling" each man, an expert in his work, has just one task to perform. He stands in one place and the particular "part" he needs is brought to him, just as bricks are carried to a bricklayer. In so highly organized a system every parts department must keep ahead of the assembling-room, so that there shall never be a shortage of any part, bolt, or screw. Progressive assembling has enabled America to make the lowest-priced, good automobile in the world.

The Motor-Truck as an Aid in Transportation

The motor-truck has been mentioned only casually; not because it is unimportant, but because nearly all the mechanism of the motor-truck was developed first in the passenger automobile. The growth of the truck industry has always lagged behind that of the passenger-car. Commercial cars are now widely used in the carrying of passengers and freight. Motor-buses are operated on regular routes in and between hundreds of cities, and carry millions of passengers yearly. In 1923 there were 3,000 motor express and freight lines in this country. In that year more than 1,375,000 motor-trucks and light commercial cars were registered in the forty-eight States, and there were 131 truck-manufacturing companies as compared with 112 passenger-car companies.

During the World War the United States shipped to our army in France nearly 55,000 motor trucks and ambulances. Field-guns and ammunition were hauled by tractors and trucks, all the army supplies were transported from the base depots

to the front by motor-trucks, and the wounded were carried to the hospitals in motor-ambulances. Motor-trucks have kept open the channels of commerce during national railroad strikes in England, France, and the United States; they have carried instant relief to sufferers in great calamities such as floods, earthquakes and fires that burned large sections of cities; and they have helped to relieve freight congestion when railroad systems were taxed beyond their capacities.

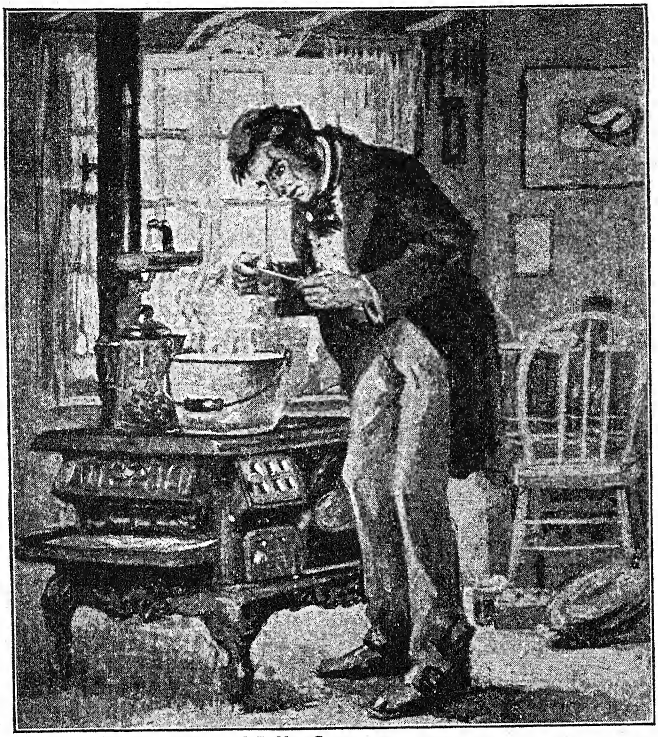
Automobiles, motor-buses, and motor-trucks are now giving such good service that they are taking the place of many electric street-car lines and short steam-railroad branches. They carry so much traffic that the building of such railways has not only ceased, but some of them are being abandoned and the tracks torn up. The faith in the power-driven road vehicle that was so strong in the earliest inventors and engineers has thus been justified by a century and a half of work and progress.

Vulcanization of Rubber by Goodyear

Goodyear's discovery of the method whereby rubber is vulcanized had as profound an effect on the development of the automobile as any other factor. Without the pneumatic tire the automobile would be little better than the heavy, lumbering vehicle with which Sir Goldsworthy Gurney and his contemporaries annoyed the countryside until curtailed by the Road Locomotive Act. On the other hand, there could be no pneumatic tire without some process of vulcanizing the rubber, out of which the tire is largely fashioned. Hence by discovering his wonderful process of vulcanizing rubber, Goodyear made it possible for us to carry heavy loads on rubber cushions and literally ride on air. Attempts are still being made to substitute springs for air-filled tires. These inventions are called "spring-wheels." They are complicated, and for the most part are unable to withstand the strain to which they are subjected when the vehicle mounted upon them sways and rocks as it travels over a bumpy piece of road. The truth is that without the pneumatic tire automobile designers would have been severely handicapped.

The water-proof quality of the sap of certain trees, when coagulated by exposure to air and cured by heat and smoke, had

long been known to natives of tropical countries. But it was not until 1730 that rubber began to be used in civilized countries. About that time a group of French scientist-explorers



Courtesy of Goodyear Tire and Rubber Co.

CHARLES GOODYEAR ACCIDENTALLY DISCOVERS HIS VULCANIZING PROCESS.

Goodyear said: "I was surprised to find that a specimen, being carelessly brought into contact with a hot stove, charred like leather. . . . Nobody but myself thought the charring worthy of notice." The outcome was the modern process of vulcanizing rubber, one of the greatest contributions to technical knowledge.

brought some samples back from South America, and Doctor Priestly, the famous British chemist, pointed out its property of rubbing out pencil-marks. Hence it came to be known as "rubber," and, because it supposedly came from the East or West Indies, it was called "India rubber." During the following century it was widely utilized as a coating in the manufacture of rain-proof coats, boots, and shoes. But the rubber was soft and had no lasting qualities.

Like nearly all the great American inventors of early days Goodyear was entirely self-taught. At seventeen he was a clerk in a Philadelphia hardware store; at twenty-one he partnered his father in the business of manufacturing buttons, spoons, scythes, and clocks. But from his earliest boyhood rubber had fascinated him.

No dealer in rubber goods dared to carry a large stock on hand. The rubber was sure to decompose, particularly in warm weather. MacIntosh, whose name is still applied to raincoats, used to caution his customers not to stand near a fire when they were wearing his water-proof garments.

At first Goodyear attacked the problem of curing rubber almost blindly. He worked by sheer inspiration, relying more on accident than scientific research for success, as he himself admitted. There was scarcely any other course to adopt. The principles of organic chemistry were hardly known at that time, and even to-day rubber remains one of our most complicated substances.

Financed by Ralph B. Steele of New Haven, Goodyear made several hundred pairs of uncured rubber boots. During the winter months they lasted fairly well, but the hot summer sun wilted them as if they had been made of candle grease. Another man would have stopped then and there, but Goodyear was merely spurred on to further effort. Leaving his wife behind to earn her own living, he went to New York and with the aid of some chemicals given him by a kind-hearted druggist again applied himself to his task. He and his family were continually in want, often he was thrust into prison for debt, but eventually he succeeded in producing rubber with the addition of magnesia and lime-water which, outwardly, was so good that in 1835 he received prizes at the exhibitions. Unfortunately, at the slightest touch of acid or vinegar the attractive surface of his rubber would disappear and reveal a doughy mass beneath.

Goodyear believed in lucky accidents, and accidents, lucky or unlucky, were plentiful enough in his life. It was a lucky accident that caused him to decorate a piece of gum with bronze and boil it in lime, thinking that lime would rob the gum of its stickiness. In the process, part of the bronze was removed, and his effort at ornamentation frustrated. To clean off the

bronze that remained on the gum, he applied nitric acid. At once the gum blackened. Goodyear threw it away. But another lucky accident caused him to look at it again some days later. The stickiness was gone! In a few days he was producing rubber cured through and through. With the aid of William Ballard of New York the firm of Goodyear and Ballard was founded. Then came an unlucky accident in the form of the financial panic of 1836. The firm failed. Goodyear was reduced to such straits that he had no money to pay his fare from Staten Island to New York and pledged his umbrella with the ferry-master, none other than Cornelius Vanderbilt.

At this period of his career Goodyear was so poor that he and his family were on the verge of starvation. Again his luck was with him. On the way to a pawnshop he met a creditor. To his astonishment the man instead of asking for money actually offered it. Goodyear returned to his family with fifteen dollars, advanced by one from whom he had no reason to expect even kind words. The fifteen dollars, however, did not long keep him from the pawnshop. One after another his possessions were pledged. When starvation again stared him in the face his brother-in-law advanced him a hundred dollars, and with this Goodyear returned to his pots and chemicals.

In 1837 Goodyear returned to New Haven, his native town. His nitric-acid process, although not perfect, was so much better than any other method of curing rubber that he succeeded in selling patent licenses. For a time he prospered. He met Nathaniel Hayward, sometime foreman of an extinct rubber company. Hayward had devised a process of curing rubber by placing it in contact with sulphur and exposing it to sunshine. Goodyear thought the process had possibilities and bought the patent, one of the few good business strokes of his life.

The remarkable effect of sulphur on rubber had already been revealed by Leudersdorff, a German chemist. Hayward, therefore, invented nothing radically new, and neither Hayward nor the German chemist knew that accurately controlled heat was necessary to complete the transformation of rubber. Goodyear carried on Hayward's process, religiously packing rubber with powdered sulphur and exposing the combination to the sun. He termed it "solarization." He succeeded in

"solarizing" thin sheets with sulphur, but when he dealt with thick coatings or masses the interior still remained soft and pasty. It was Brockedon, an associate of MacIntosh, who coined the word "vulcanization" and applied it to the sulphur process that Goodyear eventually developed.

In the meanwhile his troubles continued. The government had given him an order for rubber mail-bags, but when Goodyear returned from a brief vacation he found the mail-bags a vile-smelling, rotting mass. Life-preservers and other rubber goods vulcanized or "solarized" by Hayward's sulphur process were returned with bitter complaints by purchasers. Once again Goodyear became a familiar figure in pawnshops. And yet he could not forget the problem of curing rubber. "I had hardly time enough to realize the extent of my embarrassment," he has written, "before I became intently engaged with another experiment, my mind buoyant with new hopes and expectations." The man simply could not stop.

Again it was a lucky accident that led Goodyear to the true secret of successfully curing rubber with sulphur. Let him tell the story of the great experiment that he made in 1839:

"While on a visit to Woburn, I carried on at my dwelling-place some experiments to ascertain the effect of heat on the compound that had decomposed in the mail-bags and other articles. I was surprised to find that a specimen, being carelessly brought into contact with a hot stove, charred like leather. . . . Nobody but myself thought the charring worthy of notice. My words reminded my hearers of other claims I had been in the habit of making in behalf of other experiments. However, I directly inferred that if the charring process could be stopped at the right point, it might divest the compound of its stickiness throughout, which would make it better than the native gum. Upon further trials with high temperatures I was convinced that my inference was sound. When I plunged India rubber into melted sulphur at great heats, it always charred and never melted. . . . What was of extreme importance was that upon the border of the charred fabric there was a line or border, which had escaped charring, and was perfectly cured."

Now began a series of experiments to develop a commercially

successful process, a process in which the heat would be properly controlled. He made dozens of articles of rubber. He dressed himself in rubber from head to foot. "How shall I recognize Goodyear if I should meet him?" some one asked. "If you meet a man who has on a rubber cap, stock, coat, vest, and shoes, with an India-rubber purse without a cent in it—that's Goodyear."

Two years of abject poverty passed. No one believed in him. The winter of 1839–40 found the Goodyear family without food or fuel. A friend mercifully saved them from starvation. Yet Goodyear's determination was unabated. There were minor difficulties to overcome; the proper kneading of the rubber mass, the prevention of blisters in the finished product. "I felt in duty bound to beg in earnest, if need be, sooner than that the discovery should be lost to the world and to myself," Goodyear has written of this period. "The pawning or selling some relic of better days, or some article of necessity was a frequent expedient . . . I collected and sold at auction the school books of my children, which brought me the trifling sum of five dollars; small as this amount was it enabled me to proceed."

Borrowing a few dollars here and there Goodyear kept on experimenting, burning with the desire to sweep away all obstacles to commercial success. In the midst of his researches he was carried off to jail because he could not pay a debt. In a few months he was out again and, suddenly, found himself on the highroad to success. He paid off $35,000 that he owed. He had devised something more than a process for vulcanizing or curing rubber, and the world was ready to acclaim him. "From the vulcanizing oven," he told every one "is removed an article fundamentally changed in its properties as contrasted with its ingredients. . . . My process works no mere improvement of a substance, but, in fact, produces a material wholly new." And with this statement every chemist will agree.

Although Goodyear made his great discovery in 1839, it was not until 1845 that he patented his process. It was a costly delay. Hancock, one of MacIntosh's partners, had seen a piece of Goodyear's rubber. What is more, he had smelled it, and it smelled of sulphur. He, too, began to experiment with sulphur, and finally discovered the Goodyear process inde-

pendently. He took out an English patent in 1843, and the English market was thereafter lost to Goodyear.

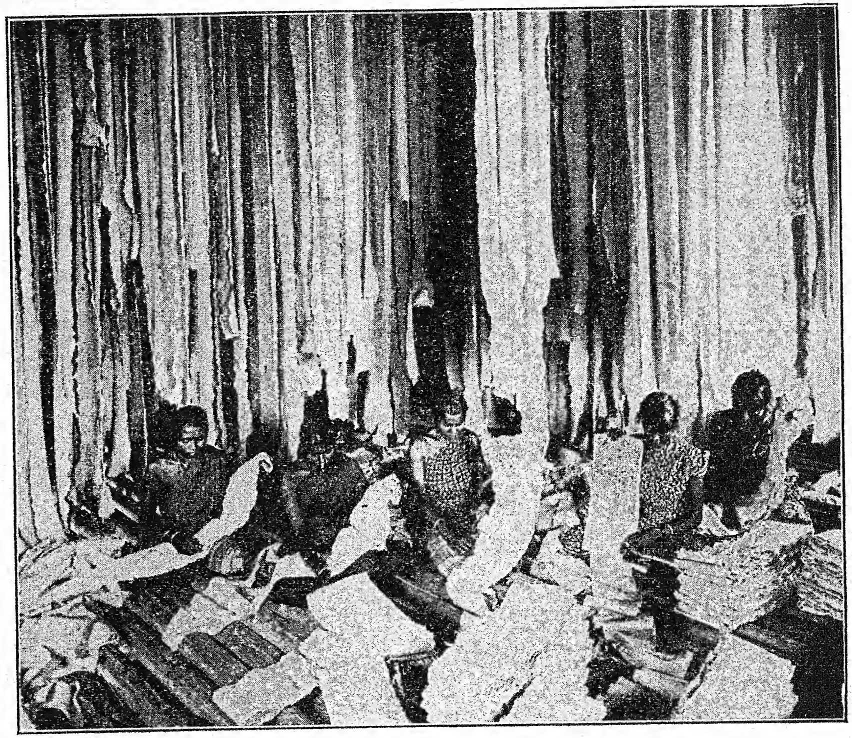
Goodyear had patent troubles at home. He had to pursue infringers at a great expense. With the assistance of Daniel Webster, who received a fee of $10,000, Goodyear defeated Horace H. Day. During the course of the trial Webster described vulcanized rubber with an originality that deserves to be remembered. He said that Goodyear's process "introduces quite a new material into the arts, that material being nothing less than *elastic metal*."

After the trial Goodyear took his family to Europe. He spent $50,000 in displaying his rubber goods to the astonished visitors of the international exposition held in Paris in 1855. His extravagance and the dishonesty of an agent stripped him of his last dollar. Once again he was dragged off to jail for debt. When he was released he posted off to England to contest Hancock's rights, and lost. Broken in health, harassed by debts, he pawned his wife's jewelry in order to buy his passage back to America. At home he flourished again for a time and resumed his experiments only to die in 1860, when the overwhelming news of his daughter's death reached him from Connecticut. Instead of a rich estate, he left behind him debts amounting to $200,000.

It is rarely that an inventor works out a process with Goodyear's thoroughness. He took out patents for every possible use of vulcanized rubber, but strangely enough overlooked its highly important application in the manufacture of pneumatic tires. This was an oversight, for in his day the merits and advantages of pneumatic tires had already been recognized.

Invention of the Pneumatic Tire

The principle of the pneumatic tire was patented by Robert William Thompson in England in 1845, in France the following year, and in the United States in 1847. Thompson's patent showed a non-stretchable outer cover and an inner tube of rubber to hold air; substantially the tire of to-day. A set of such tires with leather covers was made by a firm in Edinburgh, Scotland; they were used on an English gentleman's brougham,



Courtesy of Goodyear Tire and Rubber Company.

TWO PHASES OF THE RUBBER INDUSTRY.

Left—The latex runs down to the apex of the "V" and then down a vertical groove to a glass or porcelain cup at the base of the tree. Right—Malayan women inspecting and sorting plantation crape rubber before shipment.

and covered 1,200 miles. But Thompson's tires were in advance of their time and no one took them seriously.

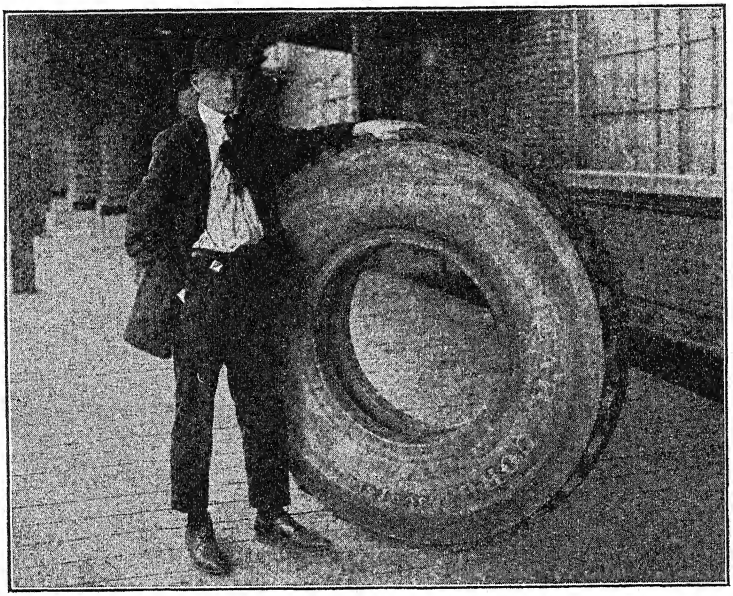
When the bicycle became popular, about forty-three years after Thompson patented his invention, the pneumatic tire was revived by John Boyd Dunlop, a horse-doctor born in Belfast, Ireland, who in 1888 and 1889 obtained English patents on a bicycle tire. Dunlop, who knew nothing about the double-tube tire invented by Thompson, deserved and received credit for his independent invention. In his school-days he wondered why a large farm-roller was easier to pull than a small one. He reached the conclusion that the bearing surface of the large roller distributed the weight. For years he occupied himself with various forms of cumbrous spring wheels provided with flexible rims that would flatten out on the road as they ran. When he had grown to manhood he began making experiments with a tricycle belonging to his nine-year-old son. He took a small disk of wood and made a tube of sheet rubber one-thirty-second of an inch thick, which he secured to the rim of the disk by a covering of linen cloth, then filled the tube with air. The rear wheel of the tricycle had a narrow solid tire. Tests were made and it was found that the air tire was "faster" than the solid one. Dunlop then made a pair of larger pneumatic tires, fitted them with proper air-valves, so that they could be inflated and covered the outer cloth with sheet rubber. He found, after several hours' test, that there was not a scratch on the tread rubber.

Dunlop next made a full-sized bicycle tire, which he presented to the Royal Scottish Museum in Edinburgh—where it is still on exhibition—and began manufacturing tires for the market. Not until a year or so later was it discovered that Thompson had already patented a similar construction. Dunlop, however, was a good business man. Undismayed by the discovery of Thompson's old patent, he formed a company with $25,000,000 capital stock, which later made profits as great as $2,000,000 in a single year. Dunlop died at the age of eighty-one, in 1921, at Dublin.

Invention of the Clincher Shoe and Rim

A year after Dunlop's patents were issued, Charles K. Welch patented a tire shoe based on fabric and having wire edges or

"beads," and also a rim to clinch the shoe, so that no other fastening was needed to hold the tire on the rim. Almost at the same time William Erskine Bartlett, an American living in England, patented a shoe with a thickened bead of fabric and rubber to conform to the in-turned flange of such a clincher



THE LARGEST TIRE MANUFACTURED.

A Goodyear 48 inches by 12 inches cord truck-tire, for fast, heavy-duty trucks.

rim, so that it was not necessary to have wires in the beads. The Dunlop Company bought this patent for $1,000,000.

The thread or cord tire was patented by John Fullerton Palmer in England. Instead of using woven fabric for the layers of the shoe, Palmer wound parallel threads spirally, covered the first layer with a thin sheet of raw rubber, then wound another series of threads over this at an angle to the first threads, and so built up a shoe that was next vulcanized to hold the rubber and all the threads together. The thread was wound just as a fish-line is wound on a stick. This form of construction produced a more flexible shoe and a "livelier" tire. It also reduced internal friction and heating of the tire as it was flattened

by the weight of the vehicle thousands of times in the course of an hour.

Pneumatic tires were first applied to motor-vehicles by Michelin and Company, a firm of French rubber manufacturers. Michelin tried hard to induce Panhard and Levassor, Peugot, DeDion and Bouton, and other French manufacturers who had entered their cars in the first Paris-Rouen motor-vehicle trial run, to equip their racing machines with pneumatic tires. They declined, saying that rubber would not stand the stress of high speed. So Michelin had a car built in his own works, fitted it with his tires, and entered it in the trial. The result was not satisfactory; but he persisted, improved his tires, and finally convinced Panhard and Levassor that he was right.

CHAPTER V

MAN CONQUERS THE AIR

THE invention of a machine which would soar with outstretched wings, like a bird of prey, was a far more difficult mechanical problem than the construction of a balloon, which has only to be filled with heated air to float up into the sky. Yet the flying-machine engaged the attention of ambitious inventors long before the hot-air or the gas balloon was suggested as a means of travelling through the air. Even in ancient poems there are tales of men who tried to fly—of the Greek, Icarus, for example, who gave his name to the Icarian Sea because he is said to have fallen into it after an unbelievable attempt to fly with wax wings that melted in the sun. Scattered through the books of philosophers and historians who wrote during the Middle Ages are unintelligible references to flying-machines built by daring adventurers and incredible reports of actual flights. But even the most imaginative story-tellers and poets never thought of rising into the air with so simple a device as a balloon filled with hot air or a light gas, until Joseph Montgolfier, of Annonay, France, actually made such an ascent in 1783. The art of weaving had been known for thousands of years. Any one might easily have made a hot-air fabric balloon centuries before Columbus discovered America. Instead, we find men dreaming of machines that were imitations of birds, probably because the example of the hawk and the sparrow was constantly before their eyes and because Nature had not populated the air with living balloons.

It remained for the United States to realize this age-old dream of flying, and for Europe to perfect the balloon and the dirigible airship. Since this book deals primarily with American achievements, and since the United States had little, if anything, to do with the development of the airship, we shall tell only the story of the airplane and what America did to make it a practical success.

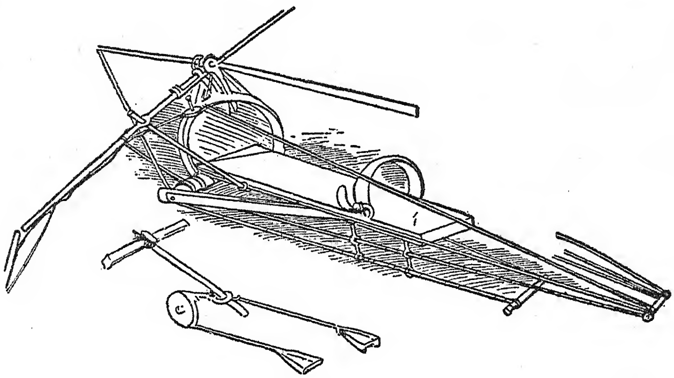
The first thinking man who saw a bird in the air probably asked himself: "Why can't I fly, too?" To be sure, he was much heavier than the air, and he knew that he would fall like a stone if he leaped from a cliff. But the flying bird that he saw was also heavier than the air, and so far as he could see, and so far as men for thousands of years after him could see, it was necessary only to strap a pair of wings to the arms in order to fly.

It takes more than a pair of wings to make an eagle out of a man. Hundreds of daring men who wanted to fly broke their necks before that truth was learned. An Eskimo would not know what to do with a lawn-mower; so the first would-be fliers did not know what to do with their wings. We have learned much about what the Bible calls "the way of an eagle in the air," and one of the things that we have learned is that we can never hope to fly by flapping or spreading wings strapped to the arms, simply because we have neither the muscles nor the physical endurance. Look at the breast of a chicken, which is just about able to fly over a fence—at the big, bulging breast muscles. And then look at a man's chest. It is evident that the bird has the breast-power to flap wings, and that the man has not. To one who knows anything at all about birds and how they fly, the winged angels that artists love to paint and carve are laughable; for all their beautiful wings, they never could fly with their weak breast muscles.

Moreover, men did not know much about the air in the beginning. They could feel the wind; but they could not see it as they could the billowing water of the sea. The air is very much like the sea—never quite still. It has its whirlpools, its upward currents and its downward currents, its countless swirls and eddies. If the air could be seen, it would appear much like the Whirlpool Rapids of Niagara. No man can hope to fly unless he can keep his machine on an even keel in this heaving, swirling, eddying ocean of air.

Plans for flying-machines were drawn up by some very able men of olden times; but few of them published actual drawings. One of those who did leave drawings which we can study and understand, was the great Italian painter, Leonardo da Vinci, who lived in the fifteenth century, about the time that Colum-

bus was voyaging to America, and who was one of the most versatile men that the world has ever known. There is no need to describe Leonardo's machine, simply because it could not have flown. It was the best attempt that had been made up to his time. Leonardo did invent the parachute, however—the



ONE OF LEONARDO'S ROUGH SKETCHES FOR A MACHINE TO BE DRIVEN BY FLAPPING WINGS.

umbrella-like device which performers at fairs use when they jump from balloons. His parachute was not an umbrella, but rather a framed, horizontal sail.

We know now that these plans of Leonardo's, and all the plans that were drawn for generations after him, down to our time, were practically worthless, chiefly because no way was provided to balance the machine from side to side

Sir George Cayley Discovers How Birds Fly

It was not until Sir George Cayley, a remarkable Englishman who flew little models about the time of the American war of 1812, laid down the few correct principles of flying that men really began to understand why birds, which are heavier than the air, are able to fly. It was thought that soaring birds, eagles, buzzards, and vultures, stay up by flapping their wings, as a hawk does now and then; but Cayley was able to prove with his models that flapping in itself has nothing to do with support. The soaring birds flap their wings just to drive them-

selves along faster than they can fall, and they are held up chiefly by the air pressure beneath their wings. A soaring bird is like a skater on very thin ice. So long as the skater skims along he is safe; but let him slow down or stop, and he breaks through the ice. It is evident why an airplane is different from a balloon or an airship—different not only in appearance, but different in the way that it stays in the air. The balloon is nothing but a bubble. It is lighter than the air, and, therefore, it floats. An airplane is heavier than air and is a constantly moving thing in flight; it must move or fall. All this Cayley worked out very carefully in his own mind, and wrote books about it, which are as good to-day as they were over a hundred years ago when they were published.

Since an airplane must be in motion before it can fly, it follows that a man in a machine cannot simply rise into the air from his back yard. The machine must run along the ground a few hundred feet, preferably in the teeth of the wind. Birds also find it hard to leave the ground. Who has not seen wild ducks flapping hard to lift themselves from the water? Sometimes a vulture is kept in a cage open at the top. Since he cannot get a running start he cannot escape. This, too, Cayley knew.

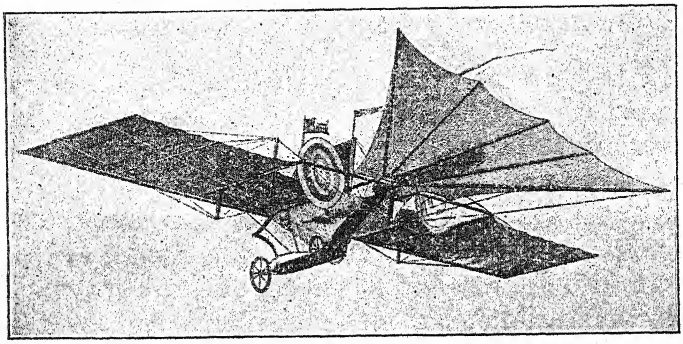
Cayley Builds a Pair of Wings

If a bird has to struggle thus to leave the ground, how is a man to do it? Cayley was ingenious. After all, birds are lifted by the air as they move along in a running start. Cayley said to himself: "I will run along the ground, too, against the wind, and then when I have speed enough, the air will lift me."

He made a pair of wings with 300 square feet of surface and built a tail upon them. Every bird has a tail. Why? To balance his body fore and aft. Apparently, Cayley was the first inventor who realized that a tail was necessary. From this simple fact it is obvious how all the inventors who preceded him floundered around without discovering the first principles of flight.

We would call Cayley's machine a "glider," because it had no motor. A man simply seized the wings and ran forward against the wind down a hill. Cayley said of this glider that it

would bear a man up "so strongly as scarcely to allow him to touch the ground, and would frequently lift him up and carry him several yards together. It was beautiful to see this noble white bird sail majestically from a hill to any given point of the plain below it, with perfect steadiness and safety." Cayley would set the tail or rudder so that the machine would ride down the wind for a few yards and then settle on the ground.



HENSON'S "AERIAL EQUIPAGE" OF 1842.

This is the first airplane planned for commerce. A small model of this machine (the full size was never built) is preserved in the South Kensington Museum. Except for ailerons, or means of warping the wings, this machine hardly differs in its essentials from modern airplanes of the monoplane type.

His was a fine attempt that did much to show others, who came after him, how to attack this hard problem; but he could never have flown in an engine-driven machine, simply because there was no light engine. James Watt had just invented the steam-engine, and Cayley, far-seeing as he was, actually thought of using it before he found that it was too heavy.

Cayley was the first man who knew that a man in a machine must balance himself in the air—balance himself in every direction.

He was followed in 1842 by another Englishman, Henson, who patented a twin-propeller, steam-driven machine—what we would call a monoplane, a machine with a single spread of wings. It had rudders, like our machines, and a tail. Indeed, Henson thought of everything, except a way to balance his flier. He knew that an airplane must be in motion before it

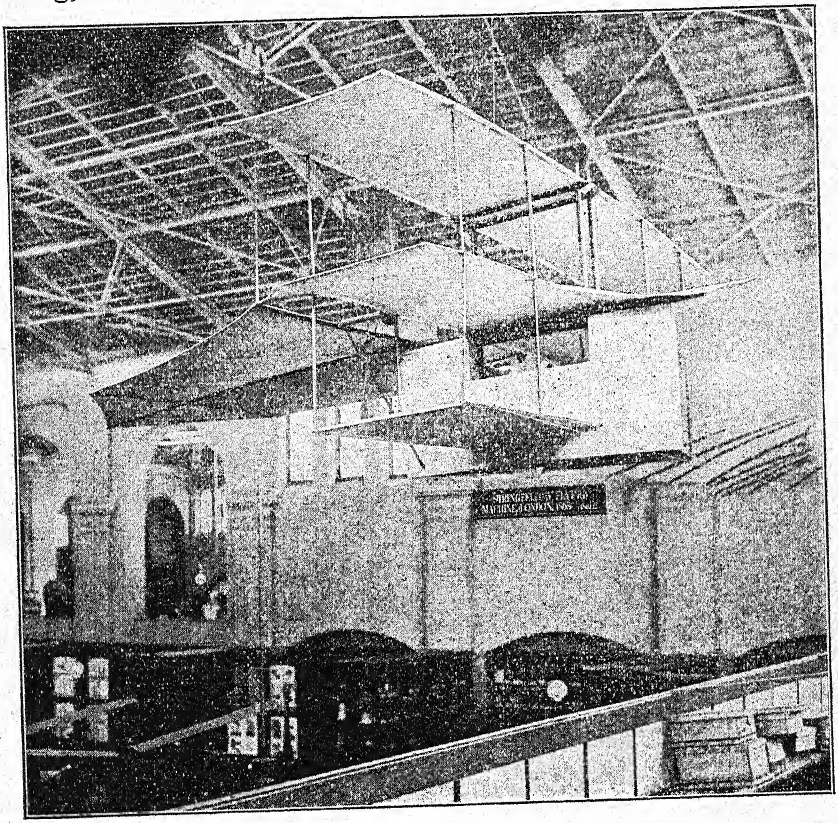
can fly, and he conceived the idea of running down an inclined track to acquire this motion—an idea that the Wrights afterward carried out, as we shall see. A few experiments were made with small models, and these showed Henson how important is the matter of side-to-side balance. A puff of wind on one side was enough to upset his model, and it was perhaps for this reason that he never built the big machine that he patented.

Stringfellow Flies a Model in 1846

Henson had a friend named Stringfellow. For a time they experimented together. Later, Stringfellow built models on his own account. In 1846 he made a little model and mounted a steam-engine within it. To launch the model he used a stretched wire. One day he got up steam, placed the model on the wire, and started the propellers. The model ran down the wire, leaped into the air, and flew forty yards. We may imagine Stringfellow almost dancing with excitement, and his unbounded joy. This was the first time, after hundreds and hundreds of trials, made in the lapse of centuries, that a power-machine, a man-made engine-driven bird had actually flown for even a short distance. There was nobody in the little machine—nothing but the little engine. But it flew! It flew!

If one surface could lift a given weight, then it would seem that two surfaces ought to lift twice as much. This is not strictly true; but two surfaces certainly can lift more than one surface. Another Englishman, F. H. Wenham, carried this principle far, and patented, in 1866, machines in which surfaces were piled on one another. This is one reason why Wenham is remembered in the history of man's conquest of the air. His was the first biplane. He even realized how great is the resistance of the air—the resistance that we feel when we run on foot or ride fast on a bicycle. This resistance increases rapidly with the speed. For instance, if a bicycle-rider doubles his speed, the resistance is not twice as great, but *four* times as great. Knowing all this, Wenham built his gliding machine so that the pilot could lie flat on his stomach in order to cut down the resistance—an idea that the Wright brothers afterward applied in their first, motorless, gliding experiments.

But Wenham had not solved the problem of balance. One evening, when the wind had died down, he took his glider out



STRINGFELLOW'S AIRPLANE OF 1868.

Stringfellow made model after model in more than two decades. In 1868 he constructed this steam-driven model, now preserved in the Smithsonian Institution, Washington, D. C. It has three superposed surfaces (an old idea of Wenham's), and was driven by a small, high-pressure steam-engine. This was the first airplane having superposed surfaces trussed and tied together in the modern manner. This model was able to fly about forty yards.

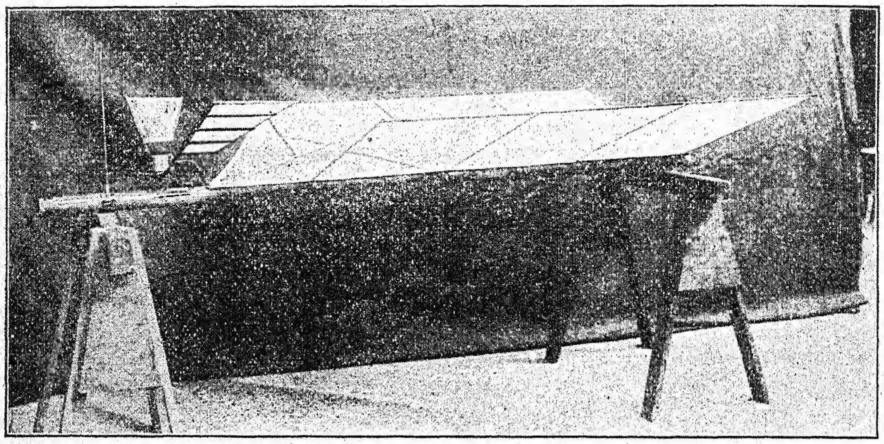
and climbed inside. A gust caught him, carried him along for a few yards, upset him and broke his wings.

Pénaud, Tatin, and Hargrave Also Fly Models

We have all seen boys sending into the air model airplanes which are driven by twisted rubber bands. Pénaud, a Frenchman, built the first of these in 1871 and gave it a certain degree

of automatic control. He put most of the weight in front, so that the model would naturally tend to dive down. But when it began to dive its rudder would lift up its head; for the rudder was fixed at just the right angle to do this. Langley, as we shall see, afterward adopted this rudder idea. Pénaud intended to build a large man-carrying machine; but he died before he could carry out his intention.

Then came Tatin, another Frenchman, who was much concerned lest his model should fly off into space, fall, and wreck



Courtesy Smithsonian Institution, Washington.

HARGRAVE FLYING-MACHINE.

In 1891, Lawrence Hargrave, of Sidney, Australia, experimented with a compressed-air model, driven by a compressed-air motor. It had no wheels for launching or alighting. The model had a supporting surface of twenty square feet, weighed about three pounds, and flew 128 feet in eight seconds.

itself. To restrain his model, he actually hitched it to a stake by means of a cord. Just as a stone whirls at the end of a string, so this model would whirl; only it did its own whirling. He had a little compressed-air engine in his twin-propeller monoplane, for such it was. After he started the motor, the model would run around and around, gracefully rise into the air and circle until all the compressed air was spent. This was in 1879.

Lawrence Hargrave, an Australian, also built air-driven models in 1891. He made many trials with different kinds of

surfaces, and out of these trials came the box kite which almost every boy has flown.

This was the state of flying when Americans began to invent airplanes. They had all the ideas of Cayley, Stringfellow, Wenham, Pénaud, and Tatin to guide them, and it was but natural that they should first make use of them before inventing devices of their own. It must not be forgotten that despite all Cayley's teaching, despite all the experiments of Henson, Stringfellow, and the rest, as yet no one knew the secret of air-flying—how to balance a machine so that it will not be upset in the wind or slip down sideways if a gust catches it under one wing.

Langley Discovers Some New Principles

Doctor Samuel Pierpont Langley, secretary of our Smithsonian Institution in Washington, had long been fascinated by the possibility of flying. Even as a boy he watched hawks on the wing and wondered why they could fly. Late in life he determined to make experiments. At first he built little models like the older Englishmen and Frenchmen—frail little models, driven by rubber bands, compressed air, and steam, which taught him what the problem really was.

Langley was an astronomer, one of the great astronomers of his time. Trained scientist, as he was, and not simply a clever mechanic, like many of the men who had invented flying-machines before him, he saw that we must know much about the air and about wings before a carrying-machine could be built. Consequently, he studied the wind and whirled plates of different sizes and shapes in the air to discover how they sailed. Here was a man who wanted important facts and not simply guesses or opinions. He worked month after month teaching himself about the wind and about surfaces, and how much may be carried in the air for each square foot of wing. Finally, he built a wonderful, steam-driven model, which was somewhat larger than a condor, and which was the first heavier-than-air machine that flew in America. On May 6, 1896, the machine flew 3,000 feet at Quantico, Virginia. The model might have flown for a greater distance, but Langley had purposely limited its fuel supply, lest he should never recover it. This

was the longest flight that had ever been made up to that time.

Langley thought: "At last I have succeeded. My work is done. Let others take my facts and build a machine that will carry a man." But who could rest after such a success? Langley knew exactly how a big machine ought to be built. He had only to make a man-carrier like the model, only much larger, of course. He simply could not rest. He had caught the flying fever.

Even after he had flown his model, not once, but time and time again, the world found it hard to believe that a man who invented a flying-machine was not a little mad. A famous man of science in Washington (his name was Simon Newcomb, and he was one of the greatest mathematicians and astronomers of his time) proved on paper, as he thought, that it was simply foolish to make any attempt at flying. He argued that a weight, such as a sack of oats, has length, breadth, and thickness. Add just a few inches to the length, the breadth or the thickness, and you can put much more oats, more weight into the sack. Assume that this sack is carried through the air by wing surfaces, with very little thickness. To carry a slightly heavier sack, the surface must be greatly increased. The professor reasoned that to carry a heavy load, wings of such size would be needed that it would be impossible to build them. And yet, all this time Langley was experimenting, and brave, patient men in Europe were spending all the money on which they could lay their hands to learn the secret of the eagle.

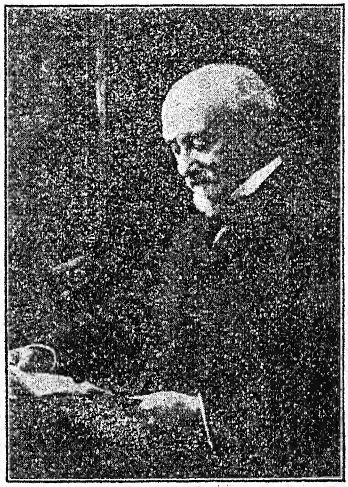
Our government became interested in Langley's invention, and Congress set aside $50,000, which Langley was to spend in building a man-carrying machine. As may be supposed, the army was in back of this appropriation of money. The generals knew that if they could send scouts up into the air they could watch the enemy and see where he was preparing to strike. Both the Union and the Confederate armies had used balloons in the Civil War, and military officers had not forgotten the fact.

Langley Builds a Big Man-Carrying Machine

Langley now proceeded very cautiously. Before building a big machine he made more experiments with models—models

about one-quarter as large as the man-carrying machine that he had in mind. As a scientist, he felt that it would be unwise to construct a large machine at once. He had to find out how much a flat surface would lift when it was moving in the air

SAMUEL PIERPONT LANGLEY.



OCTAVE CHANUTE.

Dr. Samuel Pierpont Langley, a distinguished astronomer, was secretary of the Smithsonian Institution when he began his aerodynamic studies, which resulted in the building of a small, successful, steam-driven model, tandem monoplane. With the aid of a congressional appropriation, he built a man-carrying machine, which fell into the Potomac River because it was improperly launched. The newspaper derision that followed and the failure of Congress to give further encouragement literally broke his heart. Years later, Glenn H. Curtiss modified and flew his machine successfully at Hammondsport, New York.

Octave Chanute's gliding experiments were conducted on the shore of Lake Michigan and began in June, 1896. Chanute experimented with many types of gliders, and finally evolved a method of maintaining equilibrium which was not dependent entirely on the shifting of the pilot's weight.

and whether it would lift more when it was moving fast and how much more. Then he had to determine how big a propeller must be in order to drive an airplane of a given size, and how fast it must turn. Unless he knew these facts he could not tell how powerful an engine would be needed to drive a man through the air at forty, fifty, or ninety miles an hour. Such investigations seem uninteresting and unexciting, yet, unless he had conducted them, Langley would have been working in the dark. He never popularly received the credit that be-

longs to him for his patient, necessary fact-gathering. When he had his facts and he knew exactly how big an engine he needed to drive the airplane that he was going to build with the money that Congress had set aside for him, no one could supply a motor that was strong and light enough. "It can't be done," they said—all but one. And that one delivered an engine which was light enough, but which did not have the required power.

To find an engine—a gasoline-engine—was harder than building the machine itself. Langley scoured the world for a light, powerful engine. Finally his assistant and pilot, C. H. Manly, built an engine that is still a marvel of strength and lightness.

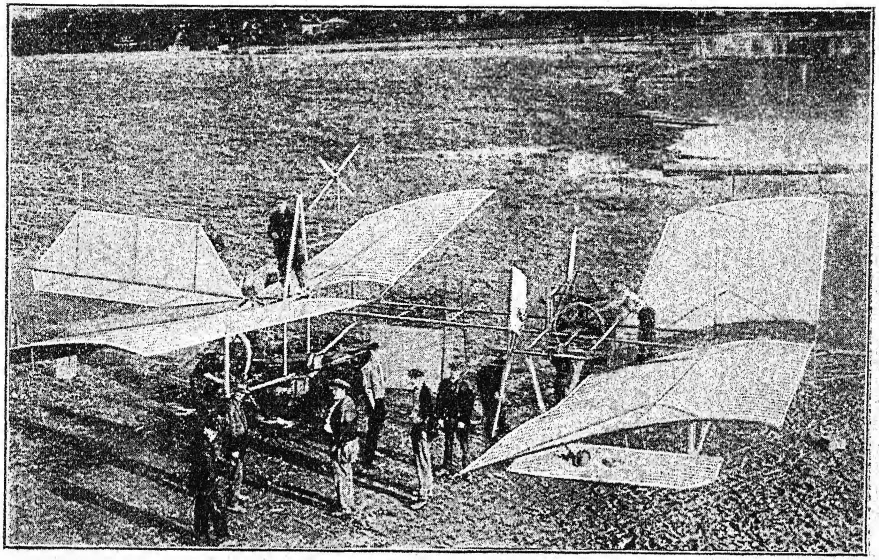
At last, Langley's big machine was finished. Like his smaller models, it was what we call nowadays a "tandem monoplane," which means that it had two sets of wings, one set mounted behind the other, each set a monoplane in itself. In the middle, between the two sets of wings, were the pilot's seat and the engine.

On September 7, 1903, the machine, mounted on top of a house-boat, was towed into the Potomac River at Tidewater, Virginia. It was to be launched against the wind from the top of the house-boat on a track. All of Langley's smaller models had been thus launched from house-boats. Manly took his seat in the machine. The engine was started. The machine was released and shot down the track. The men on the house-boat and on the tugboats in the river held their breath. So did the newspaper men who had camped on the banks of the river for days. At the end of the track a post that held up the forward wings struck something, and the machine plunged into the water instead of rising into the air. It bobbed up, however, practically unharmed, and Manly bobbed up with it.

Langley made another attempt with the same machine on December 8, 1903. This time the rear post caught, and once more the machine dived into the water. Another experiment should have been made, but the money of Congress was all spent, and the newspapers were all saying, "We told you so." The truth is that Langley's machine never had a chance to fly, because it was never launched. It would be foolish to say that

a ship would not sail because something went wrong with the launching ways, which is exactly Langley's case. Years afterward, Glenn H. Curtiss took the Langley machine and flew it at Hammondsport, New York, and thus showed how very much wronged Langley had been.

Three years after his "failure" Langley died, a bitterly disappointed man, knowing that he had built a machine, a man-



LANGLEY AIRPLANE, RECONDITIONED AND FLOWN BY GLENN H. CURTISS OVER LAKE KEUKA, HAMMONDSPORT, NEW YORK, 1914.

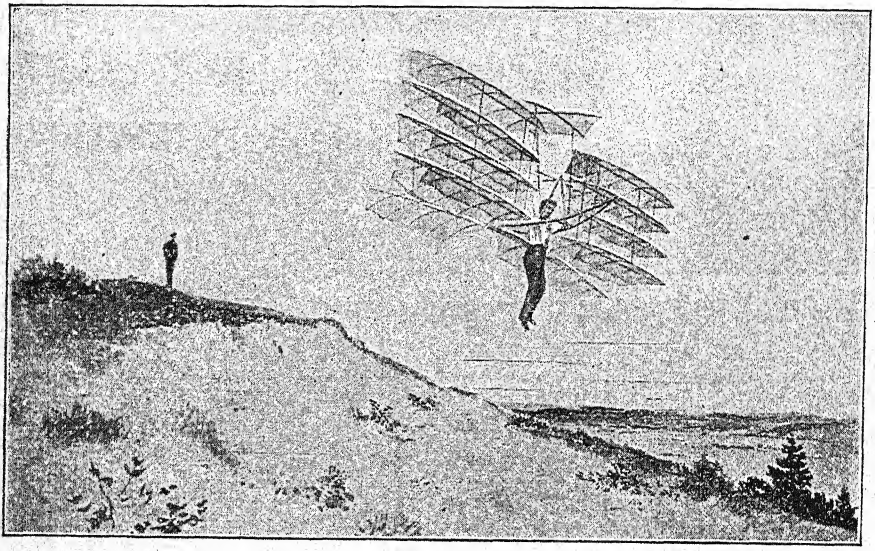
carrying machine, that could fly. Fame and glory had slipped from him. Even at this late day, the world in general is hardly aware of what it owes to Samuel Pierpont Langley, of how much he did to teach men how to fly.

Although Langley unquestionably built a machine in which a man could fly, his method of maintaining balance has not been followed. If the machine pitched or if it rocked from side to side, the pilot could shift his weight to right it. Langley also adopted Pénaud's rudder in order to obtain a certain degree of automatic stability. In other words, the horizontal rudder was mounted in back and was arranged so that it would auto-

matically lift the nose of the machine if it dived, or drop it if it lifted. Something better than this was needed. We shall presently see how the Wright brothers met the need and made flying practical.

How Mouillard, Lilienthal, and Chanute Coasted on the Air

The idea of learning how to fly by first using a pair of wings and running with them along the ground, Cayley's idea, seemed

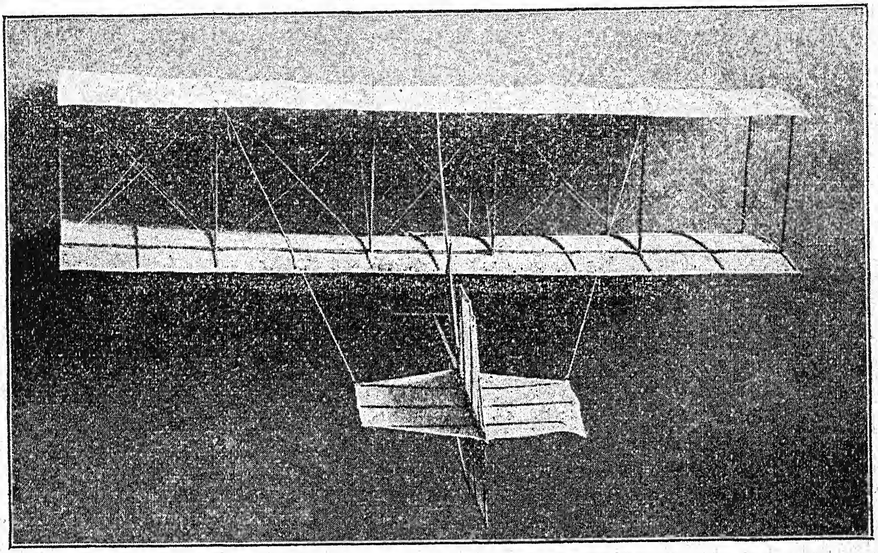


CHANUTE'S FIVE-DECKER OF 1896.

Chanute built many different types of gliders. Among them was this five-decker. Experiments were made with this machine in 1896. The glider is notable because the wings could swerve fore and aft, so as to bring the centre of lift always below the centre of gravity, thus preventing pitching. The machine proved highly successful, and eventually led to the invention of a trussed biplane glider.

so safe that many inventors clung to it rather than risk their necks in engine-driven machines. They reasoned that we must first learn how to fly and get the "feel" of the air before attempting anything more. Mouillard, a Frenchman, was one of these. He studied birds for thirty years in far-off Algeria where he had a farm. Eagles, vultures, owls, birds of all kinds he watched as they flew. He took dead birds, spread out their wings and

traced their outlines on paper. For years he studied birds on the wing. He wrote one of the most interesting books about them. After many years of patient watching and thinking, he, too, built a glider—a pair of wings provided with a rudder and with a handle-bar; this he would clutch, and would then run



Courtesy Smithsonian Institution, Washington.

THE TRUSS AS CHANUTE APPLIED IT TO THE GLIDER.

This glider, with which Chanute experimented in the later nineties, was a distinct improvement over Lilienthal's. The pilot hung below the surfaces, which were trussed and held together after the manner now generally adopted. Chanute saw that the maintenance of equilibrium was all-important. Hence he saw to it that, although the pilot was still required to shift his weight in maintaining his balance, the air pressure itself should right the machine; to this end he provided elastic wing margins, so that the centre of pressure could be varied. Many successful glides were made in this machine.

along until he was lifted from his feet by the pressure of the air beneath the wings.

It takes much money to carry out experiments. Mouillard, being a farmer, and not a millionaire, had to give up his experiments for lack of money.

Otto Lilienthal, a German, also thought that it was best to learn how to fly with gliders. He had dreamed of flying even as a boy. When he was still at school he built gliders with his

brother. All through early manhood the hope of flying in a machine of his own was ever with him. He became an engineer and a business man, simply to earn enough money with which to experiment. He worked very hard and finally became what we would call "well-to-do." Because he was a trained engineer, he had valuable mechanical knowledge that others lacked. He built wings, which were arched like those of a bird and which had a rudder; for by this time (1891) every flying-machine inventor realized that he must have something to steer with and something with which to steady the machine.

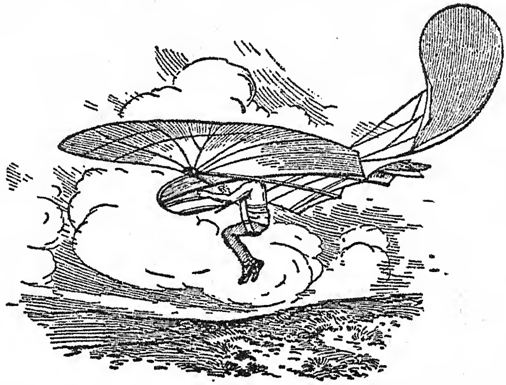
Lilienthal coasted down the air hundreds of times by running down a sand-hill. Like everybody else, he found balancing hard. If his machine tilted down on one side he would throw his weight toward the other side to right it, so that as he glided along he was constantly squirming and throwing his body about. If the birds knew that he was trying to fly, they would have screamed with laughter. It was an acrobatic performance —this quick shifting of his weight. But one day, in 1896, when he was about ready to build a motor-driven machine, when he thought that he knew how to fly, and he took his latest glider out for one last trial, he was not quick enough. The wind caught him and upset him, and Lilienthal was killed. The same fate overtook Percy S. Pilcher, an Englishman, who had been fired by Lilienthal's example.

In America, gliding experiments were also made on the shores of Lake Michigan by Octave Chanute and his assistant A. M. Herring in 1896. Both Chanute and Herring were engineers. Neither liked Lilienthal's way of throwing himself about when his glider seesawed. First they copied Lilienthal's machine, and then they built gliders according to their own ideas. Toward the last, Lilienthal had glided with two surfaces—a biplane. Chanute and Herring made gliders that had as many as five surfaces, one on top of the other, and they found these gliders steadier than Lilienthal's, and, therefore, safer. In the end, they adopted two surfaces, braced and tied together just as they are in a modern biplane. The man who glided in a Chanute biplane had to shift his weight, just as Lilienthal did, but not nearly so much. Chanute knew that it would never do to rely on weight-shifting to keep a man-carry-

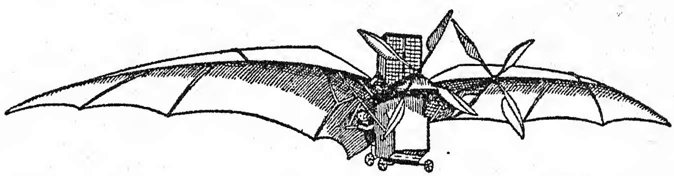
ing machine on an even keel, but, like Lilienthal, he felt that a better way of balancing would be found after men had learned to fly.

Clément Ader and His "Avion"

Some inventors thought that it was simply a waste of time to experiment with gliders. Why not build a big, power-



LILIENTHAL, THE GREAT EXPONENT OF GLIDING, IN FLIGHT WITH ONE OF HIS BIRDLIKE CRAFT.



CLÉMENT ADER'S STEAM-DRIVEN "AVION."

machine at once, leap into the air with it, and thus learn flying? Clément Ader, a rich Frenchman, reasoned thus. Like Lilienthal, he had made a fortune for the very purpose of becoming a flying-machine inventor. Mouillard's description of birds fascinated him. He must see them in Africa. Doctor Zahm, in his *Aerial Navigation*, says:

"Going to Algeria, he disguised himself as an Arab, and, with two Arab guides, journeyed to the interior where he watched the great soaring vultures, which he enticed with bits

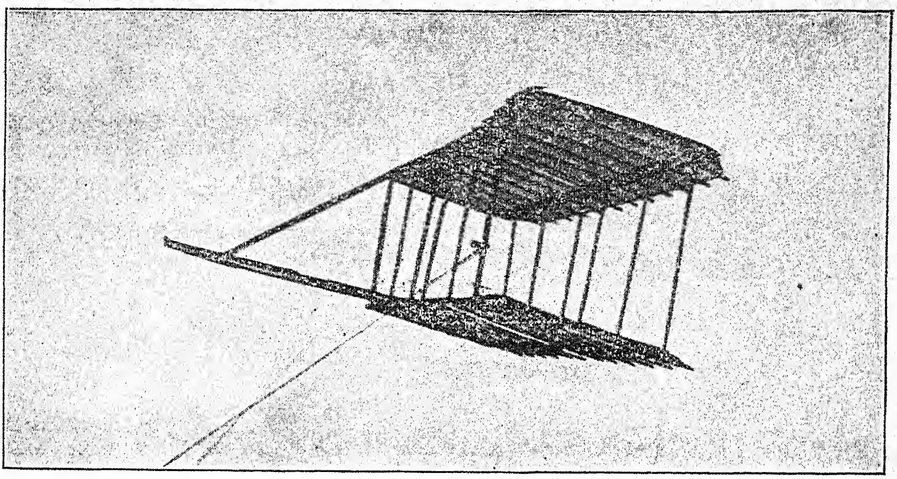
of meat to perform before him their marvellous manœuvres, wheeling in wide circles, and without wing beat, from earth to sky."

Home again in France, at the age of forty-two, Ader boldly began the building of a man-carrying, engine-driven monoplane, which he called the *Éole* and with which, according to his own account, he flew 150 feet on October 9, 1890. Then he built another which he smashed after he had flown, as he said, 300 feet. The French War Department became interested in his work and helped him build a third machine which he called the *Avion*, a name still applied to airplanes by some French writers. It took five years to build the *Avion*, and when it was finished, it looked very much like a gigantic bat. It is hard to say whether this *Avion* really flew; for the trial flights were privately made in the presence of French officers in October, 1897. Ader says that it flew, though, from his own account, it could not have made more than a hop or two. At all events, the *Avion* was smashed, and the French army lost all interest in it.

Ader had slaved forty years in getting enough money for his experiment and in building one machine after another. After spending $400,000, he retired from the field, bitterly disappointed. His *Avion* was repaired, and is now to be seen in a museum in Paris. Frenchmen point to it as the first man-carrying machine that ever flew. Perhaps it did fly. But it is certain that it was too unmanageable to be practical.

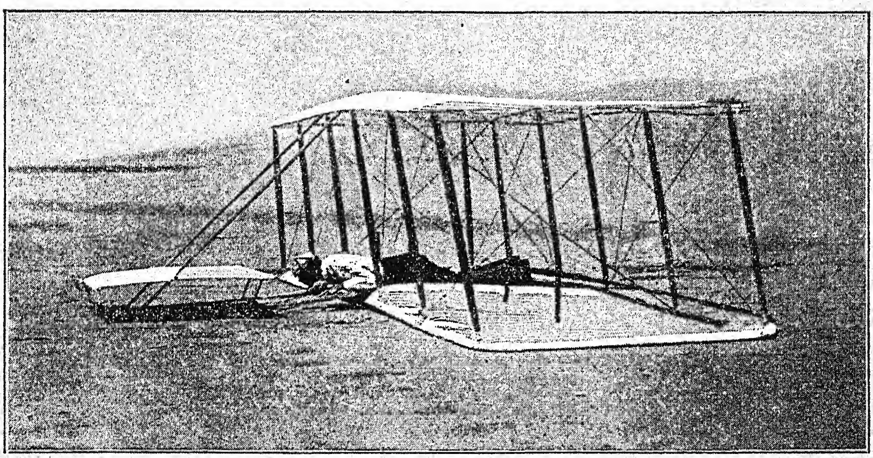
Maxim Builds a Giant Flying-Machine and Wrecks it

Hiram Maxim, a Maine Yankee who lived in England most of his life, and who was one of the most ingenious mechanics that ever lived (he invented the first machine-gun, among other things), thought just as Ader did. Why bother with gliders? "Let's build a big machine at once," he said. And build one he did. Even at this late day, Maxim's machine takes one's breath away. Compared with Ader's machine, Maxim's was a giant. Not until Curtiss built the *America* in 1914, to fly across the Atlantic, did anything larger appear. It could lift more than a ton, not counting a crew of three and about 600 pounds of boiler-water; for this was a steam-driven machine.



WRIGHT GLIDER FLOWN AS A KITE.

"We began our experiments," the Wrights have written, "in October, 1900, at Kitty Hawk, North Carolina. Our machine was designed to be flown as a kite with a man on board, in winds from fifteen to twenty miles an hour. But, upon trial, it was found that much stronger winds were required to lift it. Suitable winds not being plentiful, we found it necessary, in order to test the new balancing system, to fly the machine as a kite without a man on board, operating the levers through cords from the ground. This did not give the practice anticipated, but it inspired confidence in the new system of balance."



THE FIRST WRIGHT GLIDER.

The first successful experiments of the Wright Brothers were made with motorless gliding machines. They began in 1901. The pilot lay prone in order to reduce the resistance of the air. The horizontal rudder, or elevator, was placed in front. In September and October, 1902, nearly 1,000 glides were made, several as long as 600 feet. The next step was the installation of an engine.

Maxim was no impatient, reckless inventor, even though he thought gliding a waste of time. He finished his machine in 1893, but for years previously he had been studying propellers and surfaces, and devising engines. All these pioneers were worried by the difficulty of obtaining engines, and all had to build their own. Maxim's steam-engine is still such a masterpiece of lightness and power that had he done nothing but plan the engine we would have to regard him as a great inventor.

Of course, Maxim, engineer as he was, knew that he must have a running start to fly. Therefore, he built a track half a mile long and placed his machine upon it. He provided guard-rails to prevent the machine from rising, because he first wanted to run the machine along the track and test it out before actually trying to fly. Time and time again, the machine would leave the track and strike the upper guard-rails, proving clearly enough that it could rise into the air if Maxim would only let it do so. He had spent $100,000 in building the machine, and, bold though he was, he did not want to wreck $100,000 worth of machinery in foolishly trying to fly before he was ready. One windy day, he ran the machine out on the track to make a test. He climbed in with one of his helpers and started the engine. The propellers roared, and the machine rose from the track, as it had often done before. But this time the great bird tore the guard-rails and mounted into the air. Then it crashed to the ground and was wrecked.

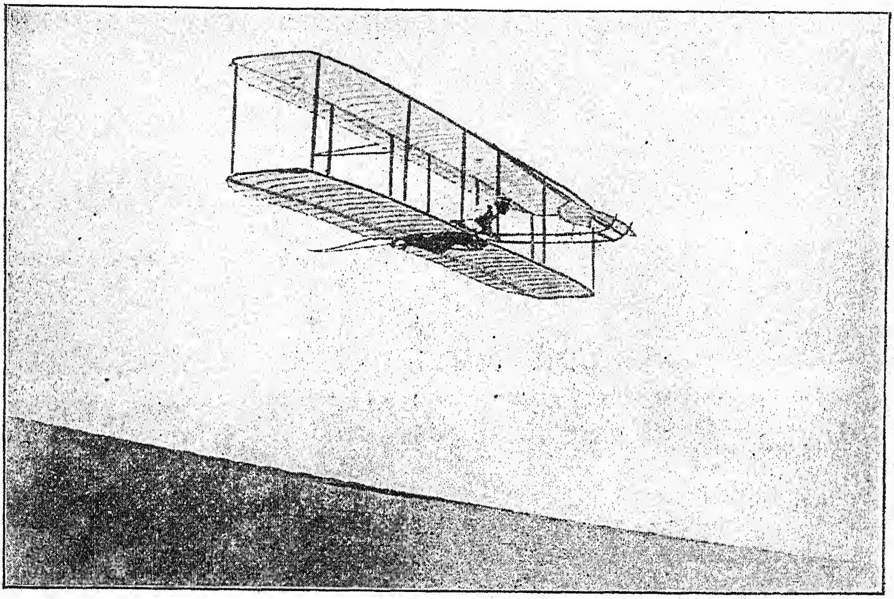
How the Wright Brothers Began

Two young men in Dayton, Ohio, who kept a bicycle-shop, reading all they could lay their hands on about flying-machines, had learned with eagerness what Langley, Maxim, Lilienthal, Chanute, and Herring were doing. They were Orville and Wilbur Wright, sober-minded, cautious, level-headed sons of a minister, who was himself of a mechanical turn. They were not engineers or scientists, like Langley, Lilienthal, and Chanute, but just practical mechanics.

"Let's build a glider," said one to the other one day. They knew that they were attacking perhaps the hardest mechanical problem in the world. Chanute had shown in his experiments

on the shores of Lake Michigan that gliding was safe in his type of machine. Hence, a Chanute glider they made up their minds to build.

They used to write to Chanute now and then, and the old man would tell them all that he knew; for Chanute was one of those rare, fine, unselfish men who try to do something for man-



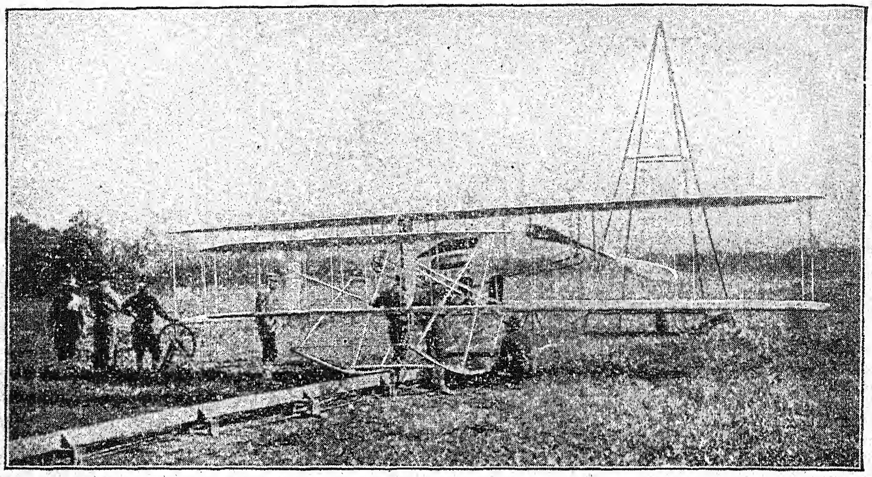
THE PREDECESSOR OF THE MODERN FLYING-MACHINE.

"With this machine, in the autumn of 1903, we made a number of flights in which we remained in the air for over a minute, often soaring for a considerable time in one spot, without any descent at all," the Wrights state in their "Early History of the Airplane." "Little wonder that our unscientific assistant should think the only thing needed to keep it indefinitely in the air would be a coat of feathers to make it light!"

kind instead of making fortunes for themselves. Soon the Wrights improved on Chanute. It will be recalled that even in Chanute's glider the pilot had to shift his weight a little so as to keep his balance, although not nearly so much as in Lilienthal's machine. The Wrights saw that this was all wrong. Some better way must be found of balancing the machine. Years before, Doctor Alfred Zahm, one of the first men who studied flying-machines scientifically in this country, had pointed out that some device must be invented to make the

air itself bring the machine back on an even keel as it tilted from side to side, a device which would increase the air-pressure beneath the falling side of a wing and thus lift it back. But how could the air be made to act thus? The Wright brothers found out.

To make the air lift the falling side of the machine, the Wrights made their wings so that they could be warped a little



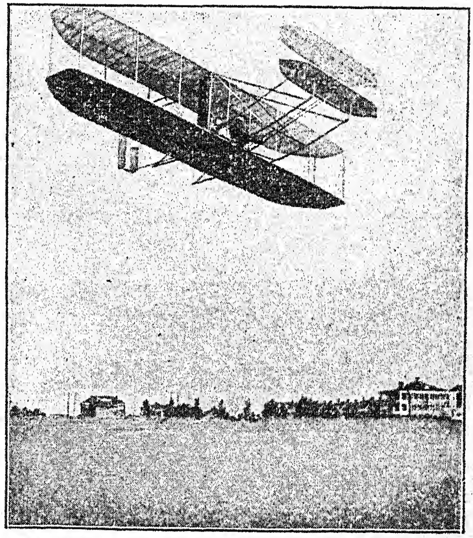
THE WRIGHT LAUNCHING-TOWER (1909).

A flying-machine must be in motion before it can fly. To acquire this preliminary motion the Wright Brothers used an inclined rail. The machine rested on a little car, which was connected by a rope with a weight that could fall in a tower. When the weight fell the car was jerked down the track, and when sufficient momentum had been acquired the elevator was tilted and the machine rose from the car. The machine after its flight landed on skids attached to the underbody.

at the rear. When a wing dropped, the pilot moved a lever to bend the rear edge of the falling side down a little. This caused the falling side to offer more resistance to the air. More resistance means more pressure. Hence, the falling side encountered more air-pressure, and was forced up. At the same time, the wing on the rising side was slightly bent up so that the air had a little less surface to press against, with the result that the rising side would drop. Simple as the trick is, it made the flying-machine practical.

There are several ways of maintaining side-to-side balance

on this principle. Instead of slightly warping the wing, flaps are used, called *ailorons*, a word which we have taken from the French and which means "little wings." These flaps are now always found on the wings of an airplane. They are hinged and



(Left) THE WRIGHT BROTHERS.

Wilbur and Orville Wright were the sons of a minister and engaged in bicycle-making when they attacked the problem of mechanical flight. They were directly inspired by Chanute and received helpful guidance from him as well as from Langley. After successfully experimenting with gliders they built the first successful man-carrying, power-driven airplane in history.

(Right) THE FIRST PUBLIC FLIGHT IN THE UNITED STATES.

This was the spectacle that greeted the army officers and the distinguished sightseers who had gathered at Fort Myer, near Washington, in 1908, to witness the first public flight of the Wright machine. The pilot sat on the lower wing, fully exposed. In front of him stretched the horizontal rudder, or elevator. Behind him roared the engine, driving twin propellers. It was a machine built with no regard for what we now conceive to be engineering niceties, but it flew, and its flying marked the dawn of a new period in transportation, and the realization of a dream as old as mankind.

they move in opposite directions. As one flap is pulled down the other is pulled up. When a pilot finds himself slipping down on one side, he works a handle or lever, so that the flap on the falling side drops and the flap on the rising side lifts. The falling flap is acted on by the air, just as it would act on a rud-

der, and lifts that side up, and, at the same time, the other side drops because the air has a little less surface to press against.

Nearly all the inventors of the past knew that two rudders were necessary—one, a vertical rudder, like a ship's, to steer the machine from side to side; the other, a horizontal rudder to guide it up or down. What the Wright brothers did was practically to give the machine a third rudder, which controlled the side-to-side seesawing. That was a very great step—the last step needed.

At Last! A Man-Carrying Machine Flies!

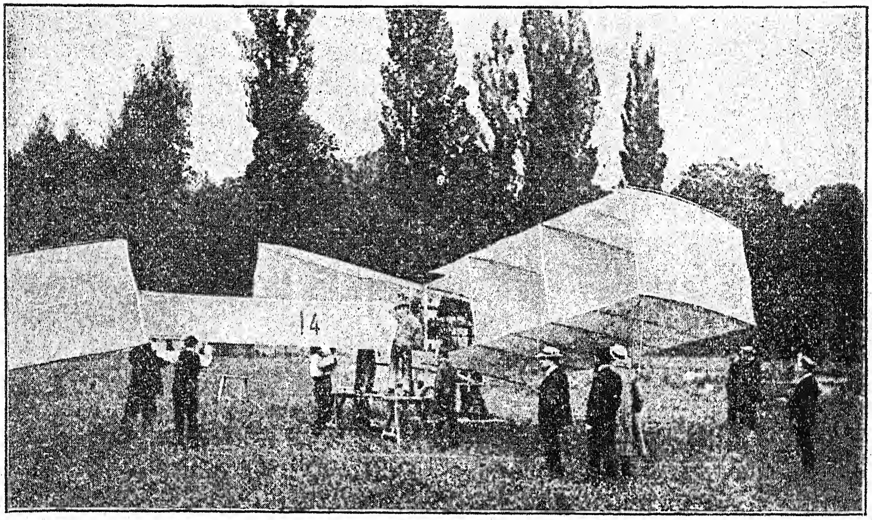
Chanute used to watch the Wrights as they glided in this machine of theirs, and he must have realized that these young men knew what they were about. They kept on experimenting with gliders for nearly three years (1900–03) and coasted down the air hundreds of times. At last, they felt that they were ready to make a trial with an engine. In 1903 they took one of their best gliders—a biplane—and mounted a very crude home-made gasoline-engine on the lower wing. The machine was not to start from the ground on wheels of its own—the modern practice. It had no wheels. In order to launch it a car was used which was to run down a single inclined track. After sufficient speed was acquired, the pilot was to tilt his horizontal rudder so that the machine would rise from the car into the air.

Many unsuccessful trials were made at Kitty Hawk, North Carolina. Then came December 17, 1903, a day of historic importance in aviation. Wilbur Wright took his seat on the lower wing of the biplane. The car and the machine upon it shot down the track. Before the end of the track was reached Wilbur tilted the horizontal rudder. The machine soared off into the air. The first flight lasted only twelve seconds; but it was a real flight. Again and again the machine was launched on that memorable day. Each time it stayed in the air a little longer. The fourth time a distance of 852 feet was covered in a little less than a minute.

The Wrights were not the kind of men to throw up their hats and cheer, but we may imagine the joy that must have been theirs. For hundreds of years the best brains in the world

had been racked to discover the secret of the eagle, and here were two American mechanics, two bicycle-makers, who had at last proved that a man can fly.

They kept on flying in improved machines from time to time —sometimes at Kitty Hawk, North Carolina, sometimes near their home town of Dayton, Ohio. A few people saw them fly



SANTOS-DUMONT'S MACHINE OF 1903.

Alberto Santos-Dumont, a Brazilian, astonished the world with this crude biplane in 1906. The machine ran tail foremost. Santos-Dumont sat in front of the wings. The "tail" could be moved to act as a rudder. To maintain his balance, Santos-Dumont shifted his body. On August 22, 1906, he made the first public flight on record in a power-driven machine. He covered a distance of 200 feet at a speed of twenty-five miles an hour, and thus won a prize of 3,000 francs offered in 1903 by Ernest Archdeacon, at a time when not even the Wright brothers had flown successfully with an engine.

near Dayton, but the Wrights did their best to keep their success secret. Theirs was a great invention, and they knew it. It was so simple that anybody could copy it who saw it and who knew of the work that Chanute had done, and Chanute had printed and published all that he knew. They cast about for a chance to sell their invention, first offering it to our government. But the United States Government had had enough of flying-machines. After their offer had been rejected, they turned to Europe. The Wrights next tried to sell their invention to Great Britain, but were again turned away.

France Takes to the Air

Just at this time a few Frenchmen were doing their best to fly, and some succeeded. The automobile-makers had perfected the gasoline-engine. It was still heavy, to be sure, but lighter than any steam-engine and boiler. So the Frenchmen ordered light gasoline-engines and put them in their crude machines.

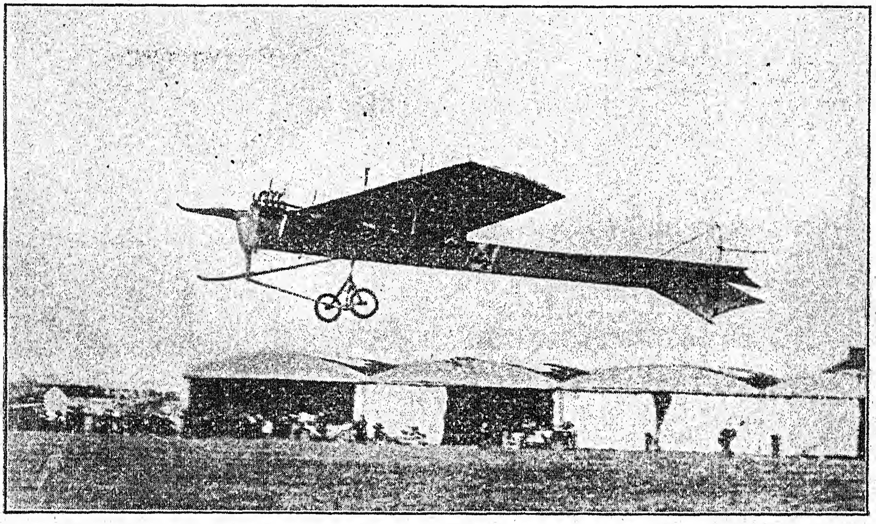
One of these men was Santos-Dumont, a Brazilian who had lived for a long time in France. He had made some remarkable voyages in balloons and air-ships of his own. He was a daredevil—this Santos-Dumont, firmly convinced that every man dies at some time that is fixed and that cannot be foreseen, no matter what he did. He was no believer in "safety first." No careful gliding experiments for him. Besides, what was the good of them? Had not Lilienthal and Pilcher been killed in gliders?

Santos-Dumont ordered a machine which looked like a big box kite. It had a rudder in front (not a new idea), and this rudder was a somewhat smaller box kite. He could move this rudder in any direction that he wished, so that he could steer himself up and down or from side to side. But he had no way of balancing himself, although he could move his weight a little from side to side. The wings were inclined at an angle to each other, and this, too, helped a little to keep the machine on an even keel.

Santos-Dumont ran over the ground in this machine, with its wheels like those of a bicycle. On August 22, 1906, he hopped into the air. A crowd watched him. It was the first time that anybody had seen a public flight. The next day (October 23) he flew 200 feet. There was tremendous excitement. Newspapers all over the world published articles about Santos-Dumont. The Wright brothers must have been worried. But when they realized that he had invented nothing that was not well known, and that, above all, he knew nothing about balancing, the true secret of flight, they must have been relieved.

A dozen Frenchmen now caught the flying fever. There was Henry Farman, a bicycle racer, Delagrange, an artist, Blériot, a manufacturer of automobile-lamps. All these men

went to Voisin, the manufacturer who had made Santos-Dumont's machine, and commissioned him to build biplanes for them. Blériot soon struck out for himself and made monoplane after monoplane. He must have smashed twenty machines before he ever flew. But even he had to learn the secret of balancing from the Wrights. Levavasseur, who made a won-



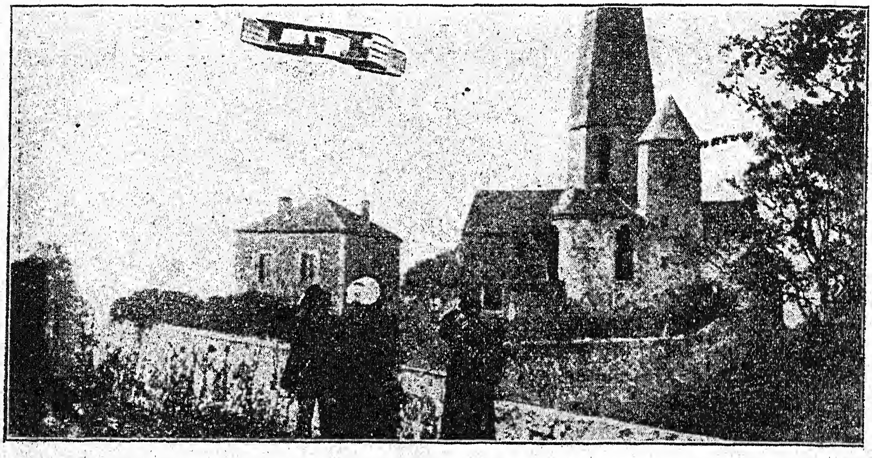
THE "ANTOINETTE" OF 1909, MADE FAMOUS BY HUBERT LATHAM.

Levavasseur was a French engineer who became famous for his light aeronautic engines, many of which were ordered by the pioneer French aviators. Later he turned to designing and building monoplanes. Hubert Latham was the pilot of these "Antoinettes"—beautiful birdlike machines that aroused the admiration of all who saw them in the early days (1909). The Antoinettes were historically noteworthy for their boat-like bodies—the first indication of modern stream-lining.

derfully light motor, also tried his hand at building monoplanes that could fly when the air was still—beautiful machines to look at. He, too, had to learn the principle of balancing from the Wrights later on.

Most of the men who ordered biplanes from Voisin did fly, but only in very quiet air. The writer of these lines remembers seeing Farman in one of the old Voisin machines—a big box kite on wheels. Farman trundled out his machine one afternoon just before sunset. A slight breeze was blowing, scarcely

stronger than a zephyr. After critically studying the flags lazily flapping against their poles, Farman decided that he would not fly that day. The wind was too strong! During the World War, aviators over the battle front flew in howling gales, which shows how quickly the trick of flying was learned,



FARMAN FLYING ACROSS COUNTRY IN 1908.

Henry Farman was a champion bicycle-rider when he took up aviation in 1907. His first machines, built by the Voisin Brothers, were simply boxlike or cellular structures on wheels, without any mechanical means of maintaining side-to-side balance. The machine would fly only in very light winds. This picture shows Farman flying in a somewhat improved machine of the boxlike type between Chalons and Rheims on September 30, 1908. The distance was twenty-seven kilometres, and the time twenty minutes. It was the first town-to-town flight on record.

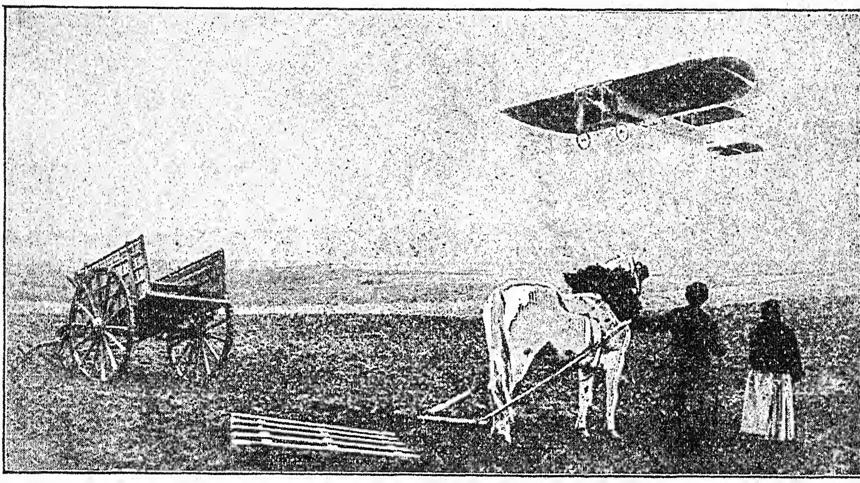
once the way was pointed out, and how stanch and powerful are the machines of to-day.

These men, particularly Farman and Delagrange (it is useless to mention the rest), flew for miles at a time. They flew across country and from town to town when the air was quiet. They won prizes—cups and money. The world saw that at last men could fly.

The Wrights Reveal Their Great Secret

Still the Wright brothers were hugging their great secret to themselves. They must have been just a little alarmed. Glenn H. Curtiss, a builder of motors and a champion motor-

cycle rider, had been engaged by Doctor Alexander Graham Bell, who invented the telephone, to help him build a flying-machine, and they felt that Curtiss might hit upon their own great secret. The United States Government now began to wake up. The army was ready to buy a flying-machine if its conditions could be met. The Wrights offered to supply one



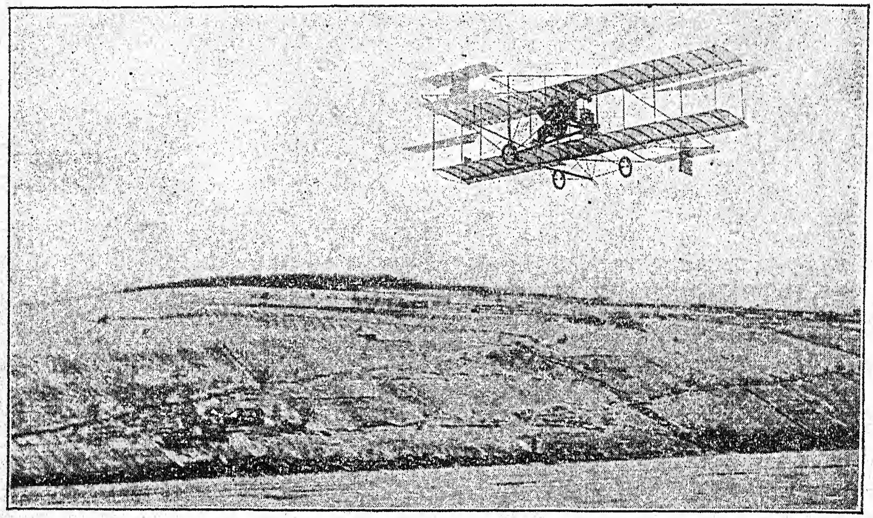
BLÉRIOT ON A CROSS-COUNTRY FLIGHT IN 1908.

for $25,000. It was clear that now was the time to show the world what they had been doing. In 1908, Wilbur Wright decided to go to France and show the Frenchmen some real flying, while Orville was to stay at home and fly another machine before the officers of the American army.

France gasped in amazement when it watched Wilbur's performance in 1908. Farman, Blériot, and the rest soon saw that this machine of Wilbur's was better than anything they had devised. Wilbur performed feats in the air and climbed to heights that were beyond them. They promptly copied his way of making the air lift the wings when they tilted over too far. Some of them warped their wings just as he did; but most of them adopted flaps or ailerons.

Our army was no less astonished at Orville's flying. Everybody thought that the army's conditions were too hard. The

speed was to be forty miles an hour with a bonus of $2,500 for every mile an hour above that. Orville wanted the bonus. If the wind was so strong that it would slow up the machine, he simply refused to fly, even though thousands had gathered to see him in the air and officers were waiting with watches in their hands to time him. He won his $25,000 for the machine



CURTISS FLYING OVER LAKE KEUKA, NEW YORK, IN 1909.

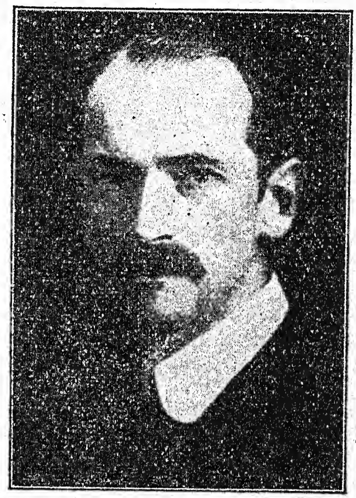
Glenn H. Curtiss had his own ideas about flying-machines. The Wrights had shown how lateral stability could be maintained by warping the wings. Since wing-warping was a patented invention, he used what have since become known as ailerons. They are little hinged planes, nowadays forming part of the main wings, but in this early machine (1909) they are mounted between the planes.

and also his bonus. The machine had more than met the army's conditions.

Now that the Wrights had come into the open, what was it that men saw? Nothing so very different from the machines with which they were already familiar, so far as mere looks were concerned. There were two wings—one above the other. That was old. The horizontal rudder or elevator, by which the machine was steered up or down in the air, thrust itself out in front; but front rudders were old. There was a vertical rudder in the rear, like a ship's rudder. That, too, was old. There was a gasoline-engine between the wings to drive the machine,

but there was nothing new in that. There were two propellers; but twin propellers had been thought of by Henson more than sixty years before. The only new idea was the method of balancing the machine from side to side, and even of that there had been glimmerings. So, there was really nothing startlingly new

LOUIS BLÉRIOT.



GLENN H. CURTISS.

Louis Blériot was a successful manufacturer of automobile-lamps when he became interested in flying. Beginning in 1900, he tried one type of machine after another, and thrilled the world with his many hair-breadth escapes. On July 25, 1909, he made the first flight across the English Channel.

Glenn H. Curtiss was a crack motor-cycle rider and builder of light gasoline-engines when Dr. Alexander Graham Bell invited him, in 1907, to provide the engines for light, strong machines built on the tetrahedral-kite principle. It was thus that Curtiss became interested in aeronautics.

about the Wright airplane after all. Yet it was the first practical man-carrying flying-machine that had ever been made and flown—one of the world's greatest inventions. We must not think that the Wrights simply copied the ideas of other men. It takes genius to know what is right, to find out why everybody before failed; and the Wrights had that genius.

Man had at last grown wings. He was eager to try them. Races were held. In 1909, Blériot crossed the English Channel and won a $5,000 prize offered by the London *Daily Mail.* Hubert Latham, in his *Antoinette*, built by Levavasseur, had

made the attempt shortly before, but had failed. He used to be the attraction at all the French flying meetings; for his *Antoinette* was a beautiful, bird-like thing to look at. James Gordon Bennett, of the New York *Herald*, offered the now famous Gordon Bennett cup and $5,000 cash for the fastest flight. Prizes for long-distance flying and high flying were awarded. It is safe to say that in a few years after the Wrights flew publicly every prize was won, except that offered by the London *Daily Mail* for a flight across the Atlantic Ocean, and that was won in 1919.

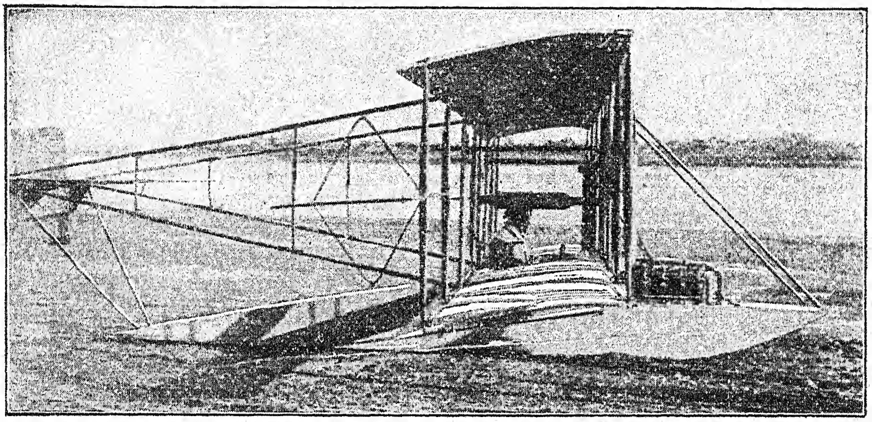
The Scientist Shows What Is Wrong with the Airplane

Most of the early airplanes had been built by carpenters and blacksmiths. As we look back at the old Wright machines and those with which Farman, Blériot, and Latham astonished the world, we wonder at the dreadful chances that were taken. Frightful accidents occurred because no one knew how strong a machine ought to be to stand the blows of the wind. Whenever a machine swoops down the wings are strained. Poor Delagrange was killed when his wings broke, and so were many others.

The engineer and the scientist stepped in. They made tests in what are called "wind tunnels," to find out just how strong machines ought to be; also to measure the resistance offered by the air in flying and to discover the best way to cut it down. A little model of a wing or strut or a body is built and held in the tunnel. Then a stream of air is blown against it. The pressure of the air against the model is carefully measured. One shape is compared with another, and that shape is finally selected which offers the least resistance.

Wind-tunnel experiments with little models have shown that not only is the wing lifted by the air-pressure beneath it, but also that it is sucked up at the top. Indeed, the suction counts for more than the lifting effect. It must not be assumed, however, that all the old theories about the effect of air-pressure beneath the wings were wrong. They were right, but not complete. Thus, the wind tunnel tells much that can never be learned in the air itself by a pilot.

Wind-tunnel experiments on models proved how great is the resistance of the wind. To fly fast, it had to be reduced. The early machines were masses of wires and struts that raked the air. The pilot simply sat on the lower wing of a biplane and watched the earth swim past between his legs. He offered enormous resistance. The wind tunnels showed that it is easier to move a correctly designed bulk through the air than



CURTISS HYDRO AIRPLANE OF 1911.

To Glenn H. Curtiss belongs the credit of having invented the flying-boat, here shown, the prototype of all modern seaplanes.

to rake it with vibrating wires and with dozens of projections. Builders were quick to learn the lesson. They built a hull for the machine, what we now call a "fuselage," and gave it the right lines so that it could part the air easily. It is a curious fact that the hull should be rounded in front and not pointed; yet the breasts of fast-flying birds are also rounded. The pilot now sits in the carefully modelled hull with just his head showing. The struts are carefully shaped to reduce resistance. In this way it had become possible to fly at speeds of over a hundred miles an hour even before the war. Now 250 miles an hour are possible.

The old machines had wings covered with fabric that was none too tightly stretched. When next you are in Washington, look at the old Wright machine which is to be seen there in

the National Museum. The wings are covered with canvas, which is not very taut. A man can stand on a modern wing—its fabric is stretched so tightly. Nowadays we use the strongest linen and treat it with what is called "dope" and then varnish it. The dope makes the fabric as stiff as a board and waterproofs it too, and the varnish protects it from the weather.

A hurricane will tear a roof off and toss it several hundred yards. An airplane travels at hurricane speed; it must, therefore, stand hard air blows. Before scientific experiments with models in wind tunnels were made, no one really knew how this thing of wires, light wood, and fabric could be made to stand the strain. The machine of to-day is as safe as a bridge, simply because builders know how hard it will be struck by the air and how lightness and strength can be combined.

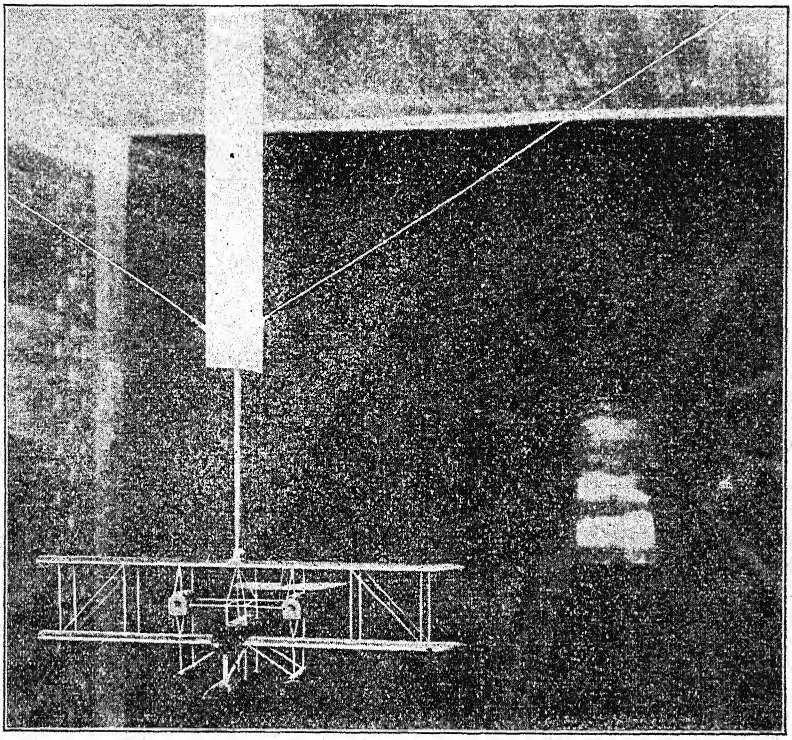
An airplane burns about as easily as a match once it catches fire. After all, it is all wood, for the most part, except the engine. "Dope" catches fire as easily as oil. Why not make the whole machine of metal—body, wings, and all? Builders thought of that long ago. But metal is heavy—much heavier than wood. Some new metals have been discovered, chiefly aluminum alloys, which will make it possible to do away with wood and linen. A German engineer named Junkers actually built a good machine of these new metals. When we fly about in the air, some day in the future, just as we now roll along in automobiles, it will probably be in an all-metal machine.

What the War Did for Flying

When the World War came, every European army had its airplanes. Yet in a few weeks all these machines, which were considered to be the last word in airplanes, had to be thrown on the scrap-heap. Every few months the Germans or the French or the English would build a machine that was a little faster than anything that had been flown before. Sometimes the Germans had the fastest machines and sometimes the Allies.

This competition did more to develop the airplane in four years than could have been expected in ten years of peace. Air-fighters like Guynemer, Fonck, Ball, and Lufberry wanted swift scouts in which they could loop-the-loop, do the "barrel

roll" or the "dead-leaf" drop, dive tail first or spin around on their beam ends. That meant stronger machines and better machines in every way. It also meant more powerful engines,



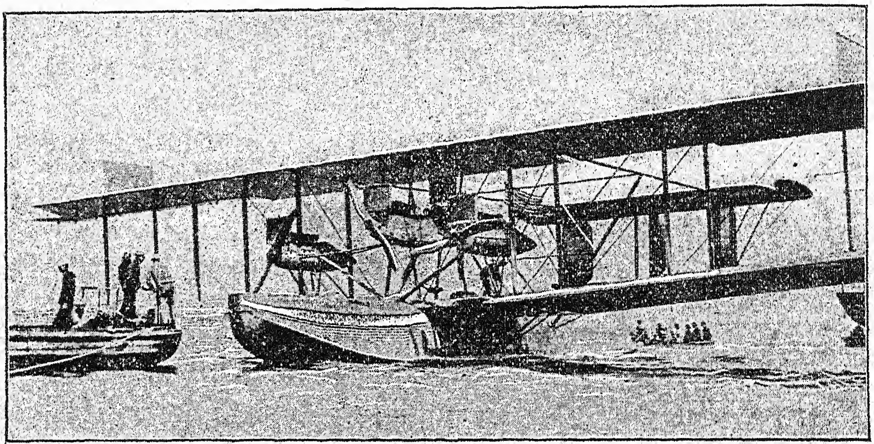
THE WIND TUNNEL OF THE UNITED STATES NAVY.

In order to design airplanes which will offer the least possible resistance to the air, small models of machines or parts of machines are suspended in a wind tunnel, and air at measured velocities is blown against them. The effects are accurately determined by instruments which measure the pressures sustained. Thus a shape is arrived at which can be driven through the air with the least expenditure of energy.

and when you use a more powerful engine you cannot mount it in an airplane that has weak wings without making it unsafe for the pilot.

The men who were sent out to drop bombs wanted machines that would carry heavier loads. Curtiss had built the big *America* in 1914, a machine with a span of 133 feet, in which Porte, an Englishman, hoped to cross the Atlantic and win the London

Daily Mail prize. When the war came, the British Government bought the machine. One or two giant machines had been built in Europe, among them the Sikorsky, which could carry as many as eighteen passengers. On the whole, there was not much experience in building giant weight-carriers before the war. The Allies started in as soon as they could to construct big machines which would carry heavy loads of bombs—good,



THE NC-4 ON HER TRANS-ATLANTIC VOYAGE.

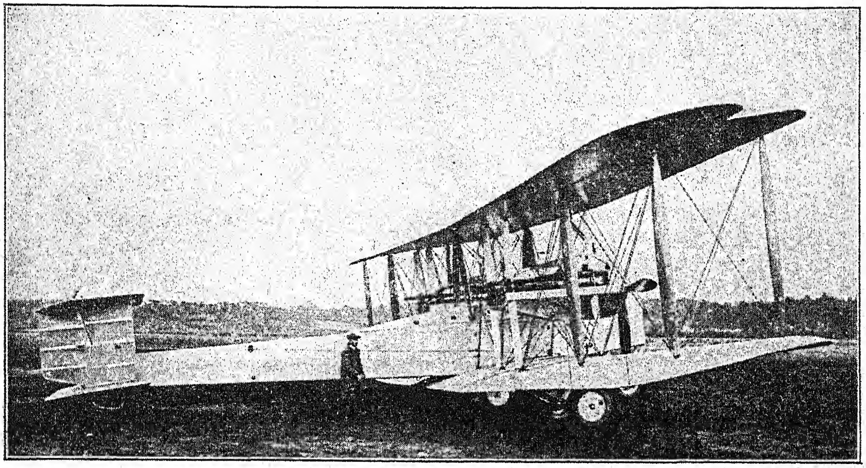
The NC-4, American seaplane, at Ponta Delgada in the Azores, on the famous trans-Atlantic flight of 1919.

practical machines that would travel several hundred miles into the enemy's country, if need be. Caproni, the Italian, made his reputation during the war with such big bomb-droppers. So did Handley-Page in England and Caudron in France. The Germans had their Gothas.

All this work did much to make regular passenger-carrying in peace-time possible, so that when the war came to an end companies were started to carry business men and tourists between London and Paris and other European cities. In Europe, thousands of people now use the airplane instead of the railway when they can. Instead of travelling a whole day by rail and steamer from London to Paris or Amsterdam, an Englishman in a hurry takes an airplane and covers the distance in about four hours.

The supreme feat, the feat that proves what may be expected of the airplane, was the crossing of the Atlantic Ocean in 1919. The Americans made the first crossing, but not in a single flight. On the other hand, the English flew in a single stage from Newfoundland to Ireland.

American naval officers first crossed the ocean, not with any hope of winning the prize of $50,000 offered by the *Daily Mail*,



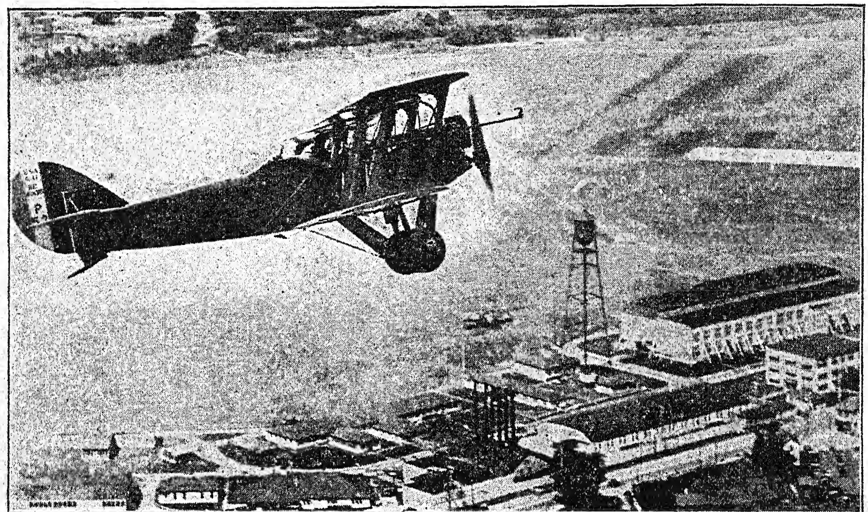
THE AIRPLANE THAT FIRST CROSSED THE ATLANTIC OCEAN.

On June 15, 1919, this Vickers-Vimy-Rolls airplane landed at Clifden, Ireland, after having completed the first direct flight across the Atlantic from St. John's, Newfoundland. The machine was piloted by Captain Sir John Alcock, and navigated by Lieutenant Sir Arthur W. Brown. The ocean was crossed in a single stage at the high average speed of nearly 118 miles an hour—a speed made possible by the favorable following winds.

but chiefly to collect facts that would help others to cross the Atlantic. Indeed, there was no chance of winning the prize. The conditions of the *Daily Mail* required that a non-stop flight be made, whereas the navy planned to fly from New York to Newfoundland, then to the Azores, then to Portugal, and finally to England. Our naval officers made long and careful preparations. They took every precaution conceivable to insure safety. All the way across war-ships and destroyers were stationed to send wireless weather reports to the men in the air and to help them as much as possible.

Every care was taken to make the voyage of the three great

navy seaplanes NC–1, NC–3 and NC–4 a success. Commander John H. Towers, captain of the NC–3, headed the little air fleet; Lieutenant-Commander Albert C. Read was in charge of the NC–4; and Lieutenant-Commander Patrick N. L. Bellinger commanded the NC–1. The planes could hardly carry enough



Courtesy U. S. Army Air Service.

THE MACHINE IN WHICH MAJOR SCHROEDER BROKE THE TWO-MAN ALTITUDE RECORD.

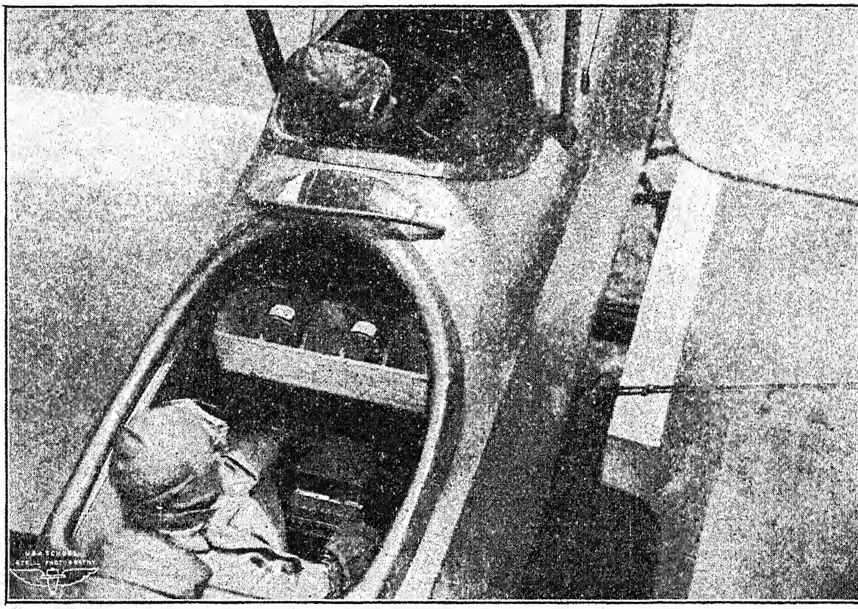
In the modern fast airplane, as this picture shows, careful attention is paid to what is called "stream-lining," which means that fuselage, wings, struts are so designed that the whole parts the air easily. The old machines were a mass of projections that raked the air and thus made high speed impossible. In this machine (a Le Père), Major Schroeder broke the two-man altitude record.

fuel to make one long flight to England, which is one reason why it was decided to cross in several stages.

On the morning of May 8, 1919, the three great sea-birds took the air at Rockaway, near New York city. Later, the three seaplanes met at Trepassey and made the final preparations for the great flight. The real trip across the Atlantic therefore began at Trepassey, Newfoundland.

On the evening of May 16, the three seaplanes leaped into the air for the long flight to the Azores. As they sailed along, a destroyer below would send up a column of smoke by day and

flash search-lights or star-shells at night, so that the men in the air might know where they were. Thus the bold airmen flew over the station ships below, one by one. They were nearing the end of the jump to the Azores, 1,380 miles long, when they ran into a thick fog. The pilots could see nothing. All about



Courtesy U. S. Army Air Service.

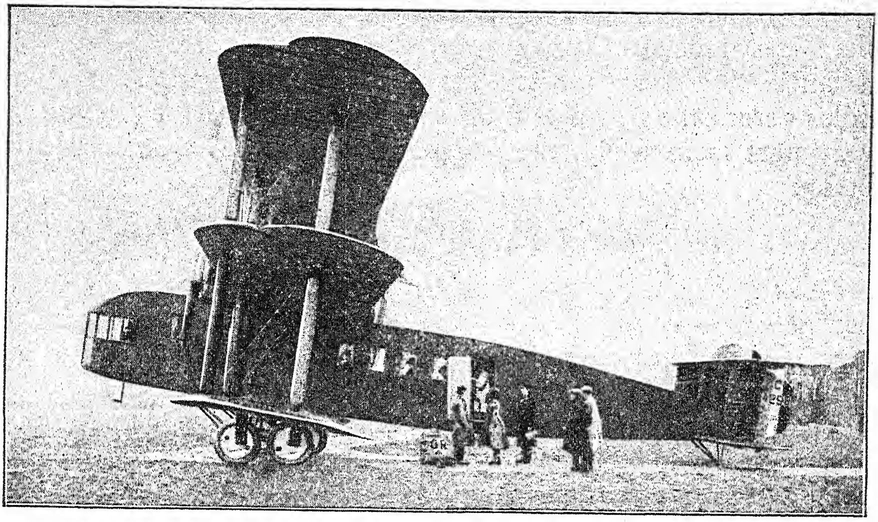
COCKPIT OF A MODERN MILITARY AIRPLANE.

In the early Wright machines the pilot and his passenger sat on the lower wing with no protection whatever; they were not even suitably clad. They saw the earth swim past between their legs. In modern machines, the pilot and his passenger sit in a boatlike cockpit with only their heads protruding. They are protected not only by the cockpit but also by helmets, goggles, and leather coats lined with sheep's wool.

them was this thick mist. They could not climb up out of it. Everything depended on cool heads and stout hearts. At last, the NC–4 managed to climb out of the fog and arrived at Horta in the Azores, fifteen hours and thirteen minutes after she had left Newfoundland. The NC–1 and NC–3 both had to alight on the water. Lieutenant-Commander Bellinger and his crew were taken off the NC–3 by a steamer and landed at Horta. The NC–1 had been badly pounded by the waves, and her crew worked desperately to keep her afloat before they were taken off.

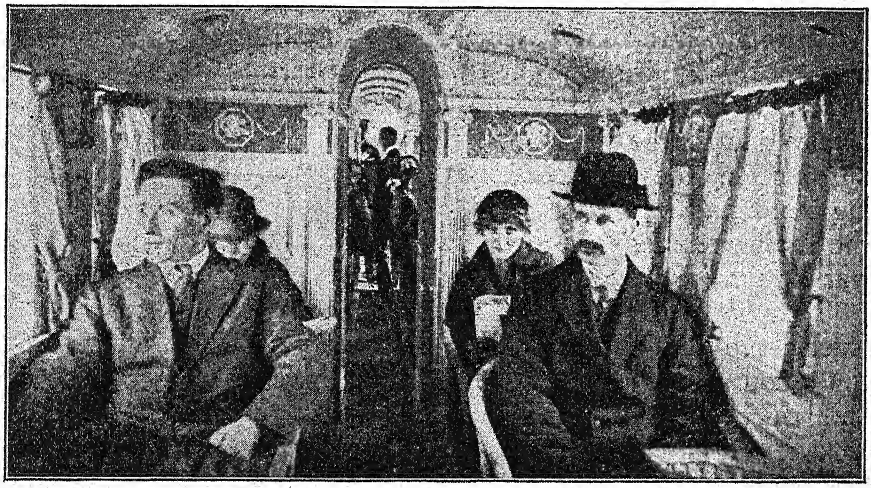
The men of the NC–3 had a terrible experience. All during the night a rain-storm beat upon her and all the next day she had to face a gale. She could not tell where she might be found; her wireless apparatus could be used only in the air because the current was generated by a little propeller driven by the wind as she sped along. As for seeing her—she was about as easy to see on the ocean as a speck of dust on a plate-glass window. High seas began to break over her; the ribs of the lower wings cracked and the fabric that covered them split. Finally, the elevator was swept off. The hull leaked badly, so that the pumps had to be kept going to keep the ship afloat. With a shout the men greeted the sun, which all at once came out. Thirty-five miles away they saw a mountain. In a desperate attempt to reach land they let the wind blow the NC–3 along as it would a sailboat. Night fell again. Still the heavy sea tossed the frail vessel about, and still the storm raged. By daylight nothing was left of the lower wings except a few of the heavier beams. Early in the morning San Miguel hove in sight. Seven miles off Ponta Delgada, the battered NC–3 was sighted. A destroyer steamed out at full speed to help her. But the men on the NC–3, for all the hardships that they had endured, would not give up the ship. They brought the NC–3 into the harbor under her own power, "taxiing" over the waves, a mere floating wreck. They had been in the water fifty-three hours, making desperate efforts to reach port, and had suffered hardships. Their sandwiches had become soaked with sea water and could not be eaten. They had only a few pieces of chocolate. Rusty water from the radiator was all they had to drink.

Only the NC–4, commanded by Read, was fit to keep on, and keep on she did. Early in the morning of May 26, 1919, she left Ponta Delgada, to which she had meanwhile flown from Horta, and started on the 891-mile flight to Lisbon. She made the run in nine hours and forty-three minutes. All Lisbon cheered, blew whistles and waved handkerchiefs and flags when she came down into the harbor. After a rest of three days, Read started for England on the last leg of the flight. A leak in one of the engines made him come down at Figuera, but after making repairs he started again. On the afternoon of May 31,



BRISTOL PASSENGER-CARRYING AIRPLANE.

After the Great War ended, the leading manufacturers of airplanes saw that the immense amount of research that they had conducted in order that they might be able to build bombers of enormous size and carrying capacity might be turned to commercial account. They immediately began the building of passenger-carrying machines, of which this huge Bristol "Pullman" is a type. The interior of this machine is reproduced in another picture.



INTERIOR OF A LARGE PASSENGER-CARRYING AIRPLANE.

The passengers sit comfortably in an attractively designed body (fuselage), which is electrically illuminated, and on which there is even a small washroom. The carrying capacity is about twenty.

the NC–4 reached Plymouth. For the first time in history the Atlantic had been crossed by air. The long flight of 4,500 miles across the ocean and up the European coast ended at the very port from which the *Mayflower* had sailed three centuries before.

The English Flight across the Atlantic

Three airplanes were sent over from England by as many companies to make a non-stop flight from Newfoundland to Great Britain in a single stage, and thus win the prize of $50,000 that had been offered by Lord Northcliffe, owner of the London *Daily Mail*, to the man who would first cross the Atlantic in a non-stop flight. The money itself hardly tempted the English companies that sent machines and crews across; for the long preparations and the wear and tear on the machines cost far more than the $50,000 to be won.

Harry G. Hawker and Lieutenant-Commander H. Grieve were the first to take the air from St. Johns, Newfoundland, on May 19, 1919, in the great contest. Theirs was a Sopwith biplane driven by a Rolls-Royce engine. It was a mere trifle that prevented them from being the first men to cross the Atlantic by air. Their engine, like most automobile engines, was cooled by water. A strainer in one of the pipes leading from the radiator clogged, so that the water boiled away. Every one knows that when the cooling water gives out in an automobile, the engine is overheated and then stops. Realizing what had happened, Hawker changed the course back over the main steamship lane and zigzagged about. At last a ship was sighted and Hawker came down.

Nothing was heard of Hawker and Grieve for six days. Every one thought that they had been drowned after losing their course. They had flown 1,100 miles in fourteen hours and thirty-one minutes when they met with their accident. In a few more hours they would have sighted land. The two brave air navigators arrived in London amid cheers. A consolation prize of $25,000 was given them.

One hour after Hawker and Grieve started, Captain F. P. Raynham (pilot) and Captain F. W. Morgan (navigator) rose into the air, also from St. Johns. They were not quite ready

to leave, but Hawker and Grieve's start spurred them on. Their Martinsyde airplane was so heavily loaded with gasoline for the long voyage that it was wrecked before it left the ground, and Raynham and Morgan were injured.

On June 15, 1919, the third machine took the air—a Vickers-Vimy biplane driven by a Rolls-Royce engine and manned by Captain John Alcock and Lieutenant Arthur Brown (the latter an American).

Alcock and Brown's trip across the Atlantic was short but terrible. Half an hour after they left Newfoundland, a part of the wireless set gave way. They could not let a world, which was literally holding its breath, know how they fared. Nearly all the way over they were either in fog or flying between banks of fog, so that they could not see the water most of the time. A flying-machine always drifts from its course—how much, the pilot notes by watching the waves of the sea or the ground. But Alcock and Brown could not see the water, so that, for all they knew, they were drifting away from the right course and might never reach land again. Luckily, they caught a glimpse of the sun, the moon, and a star or two, so that they could calculate their position. Most of the time they sped along at a height of 4,000 feet. Flying in a fog makes it hard for a man to know whether his machine is on an even keel or not. When Alcock once swooped down to within fifty feet of the sea to get what he called his "horizon," which means his level, he found himself flying almost on his back. And he never knew it until he saw the water! To be sure, he did not fly very long in that position—only a few minutes probably. So thick was the fog that the two men never saw the sun rise. Once they climbed up to 11,000 feet and ran into hail and snow. Brown had to stand up and chop off the ice from the instruments. Think of that two miles in the air!

Alcock and Brown covered the distance of 1,960 miles between Newfoundland and Ireland in sixteen hours and twelve minutes—less than the time that it takes the Twentieth Century Limited to run from New York to Chicago, which is only half the distance. The speed of the airplane was about 120 miles an hour, which is due to the fact that a following wind helped the machine along by about 25 miles an hour.

PART II

COMMUNICATION

CHAPTER I

THE STORY OF THE PRINTED WORD

JOHANN GUTENBERG set up a printing-press at Mainz, Germany, in the year 1450, and his "movable types" were the wonder of his day. Until his time, books had been printed from wooden blocks, each engraved with the reading matter of a page. The modern amateur's movable types are better than his. Gutenberg, who had to ink his type with a leather ball, would have been delighted with a modern printer's hand-roller. Far from thinking the amateur's cheap hand-press a toy, he would have regarded it as a marvellous machine, with its ink-roller passing over the type automatically, its ink-table, its handle and leverage giving such strong, even pressure with so little effort.

Gutenberg really printed his books on a wooden cheese-press. His type was laid on a moving table, and inked with the "printer's ball." A sheet of paper was laid on the type, and the whole covered with a blanket. Then the type form was pushed under a wooden plate, or "platen"—the part that presses the paper against the type—and the platen was screwed down tight. After a sheet had been printed, the platen was screwed up, the type-table or "bed" drawn out, the type inked again, and the operation repeated. Printing was hard work, requiring strong muscles. The platen "wabbled," the press squeaked, and a printer could make perhaps fifty or sixty imprints or impressions an hour.

Yet it is generally conceded that all modern printing began with Gutenberg. If Gutenberg could see one of our big newspaper or publishing plants he would marvel at the fast type-setting-machines and the great perfecting presses. All the work of inventors since his day has been centred on printing faster and faster, and cheaper and cheaper, and more and more. The old gentleman would probably remark that the demand for his printed books, in the year 1450, was more than he could

meet. It has been so ever since; and for this reason the improvement of printing machinery has always fascinated the inventor.

A job of printing begins with the setting of the type by the compositor. Sometimes the page is printed directly from the type, but electrotype plates are usually made from it. Then comes the actual printing by what are still called "presses," although they do not press paper upon the inked type itself, as did Gutenberg and printers for several generations after him. Presses now are machines for *rolling* paper against printing-plates. Composing-room, plate-making room, and press-room are the three great departments in a modern printing-establishment, and the story of the printed word can be followed by taking up each in its turn, just as a job of printing passes through a publishing-plant.

Gutenberg did not really originate printing, although he is often given credit for it. He made it easier, quicker, and cheaper by inventing "movable types." This invention is so important that it marks the beginning of a great period in human history —the period of modern education.

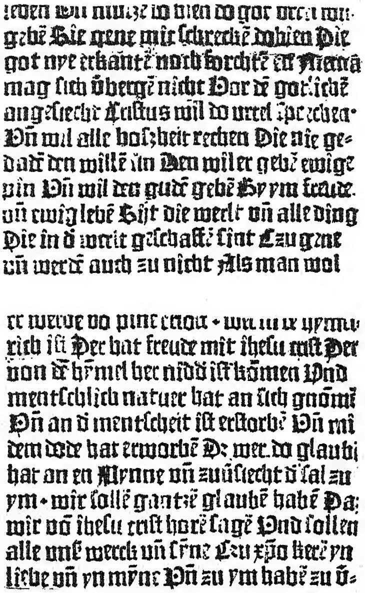
The first printer lived so many centuries ago that all trace of him has been lost. His printing had to do, not with books, but with patterns on cloth. He drew his pattern on a block of wood, and then cut it out to leave a raised design. He dipped his cut block in dye, and pressed it on the cloth. As far back as the sixth century, the Chinese learned to cut the letters for the page of a book on wood and print from the wood by hand. The Japanese were printing books from wood-blocks, too, in the eighth century; Europe began in the twelfth century. Pictures were printed from wood in two or more colors, such as the famous Japanese "prints" which are so highly prized by collectors. Such printing did not demand machinery. Any skilful man could print, once the blocks were made.

"Movable Types"—The First Great Idea

But it took much time and money to make several hundred printing-blocks for a book. Publishers could not profitably issue many books in so costly a way, and few readers could af-

ford to buy them. The world's early books were written on parchment, by hand, and only a few rich noblemen owned books, much less libraries.

"Why not cut separate letters on small blocks of wood, and arrange them to print the words on a page?" was some inven-



(Left) THE OLDEST EXAMPLE OF PRINTING FROM TYPE.

Obverse and reverse of a page printed by Gutenberg in 1445 or 1446. The specimen of Gutenberg's work here presented is a German consideration of the end of the world and of the Last Judgment.

(Right) WOOD BLOCK USED BEFORE THE INVENTION OF MOVABLE TYPE.

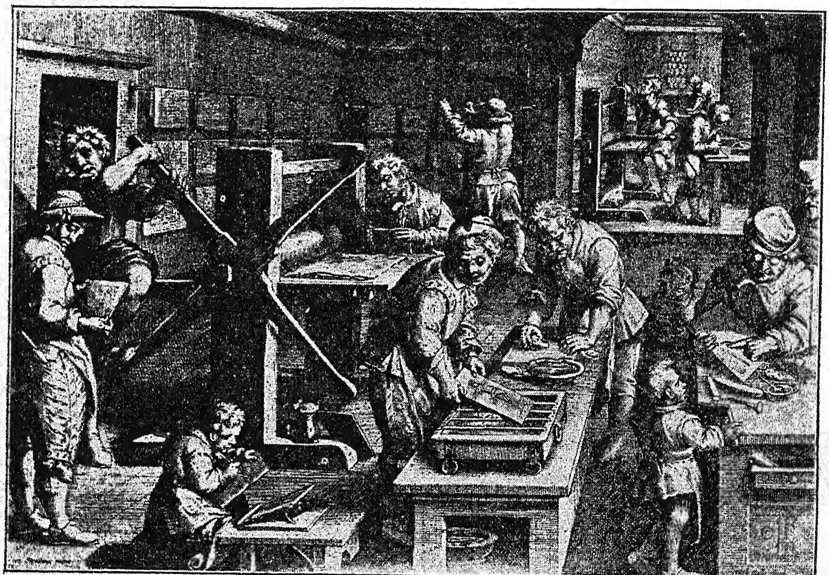
(From a wood-cut dated 1423, the earliest European dated wood-cut known.)

tor's thought. "Then separate the letters after printing and form the words for the next page?"

It was a great idea! But it is hard to say who thought of it first, for the question has been discussed more than 400 years. Johann Gutenberg, the German (born 1397—died 1468), has been given most of the credit, but the Dutchman Laurens Janszoon Coster, of the city of Haarlem (he lived between 1370 and 1440) may have been the true inventor. Some historians think Gutenberg merely improved movable types invented by

Coster between the years 1440 and 1446, and that some of Coster's types were stolen and taken to Gutenberg, who copied them. There is enough evidence in favor of Coster to make out a very good case for him.

It is certain that the first books were printed from movable types about 1450. Printed books soon became more com-



From an engraving by Stradanus, circa 1585.

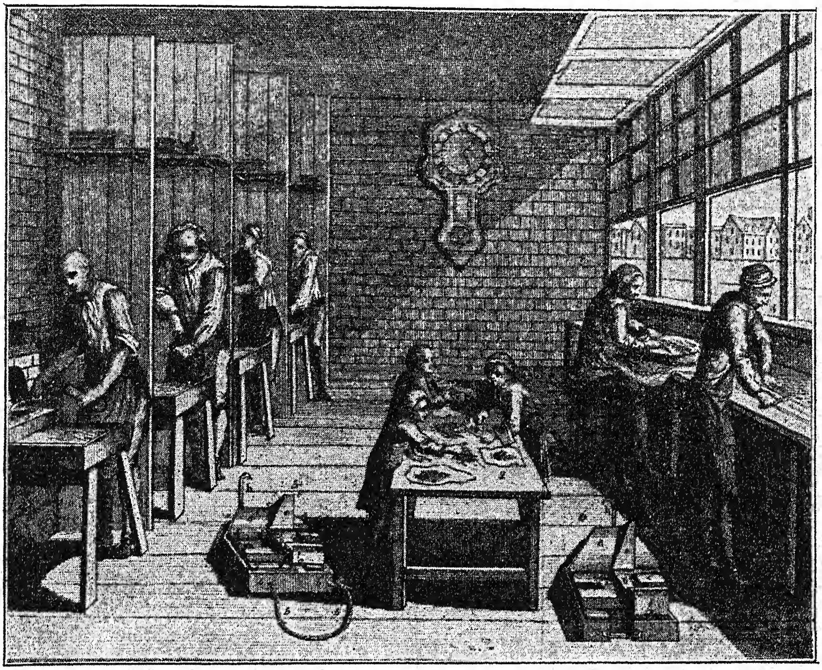
COPPER ENGRAVER AND COPPER-PLATE PRINTING-PRESS OF THE 16TH CENTURY.

This is the old "cheese-roller" type of press.

mon, and even cheap, for those days. Hence, more people learned to read, and more authors wrote books, until "news books" were in demand, and then "news papers," of which the first are believed to have appeared in Germany and Italy before the end of the sixteenth century. The oldest newspaper known by name is the German *Frankfurter Zeitung*, founded in 1615. The first newspaper in the United States was *Publick Occurrences*, started in Boston in 1690.

The first movable types were large, because the early printers copied the large letters of hand-written manuscripts. Hence the page of an early printed book appears as though it

had been lettered by hand. Moreover, large letters were doubtless easier to cut than small ones. But hand-cut letters soon gave way to metal type cast in a mould. A mixture of lead and tin was used—type-metal, as it is still called. These metal types wore better than wooden ones, and thousands of them



TYPECASTING IN ENGLAND IN 1750.

A method which remained in vogue practically until the invention of the linotype and monotype in the 19th century.

could be cast from one mould. Printers made their own types at first, but before printing was a hundred years old the making of types became a business in itself. The first "type-founders" set up shops in France about the middle of the sixteenth century.

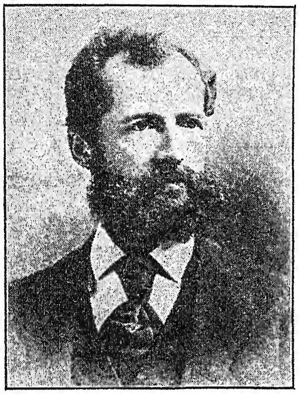
The first successful type-foundry in America seems to have been established by Christopher Sauer, in Germantown, near Philadelphia, in 1772. Several others had tried their hand at casting types and failed. Among them was Benjamin Frank-

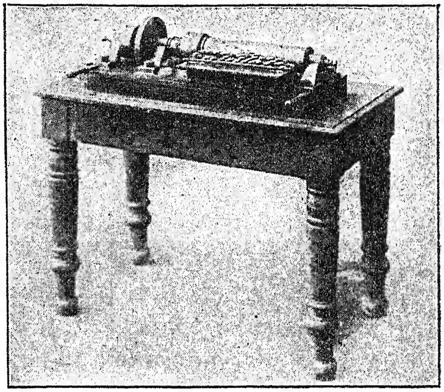
lin, who was a printer, and wanted "sorts" or extra types of a certain letter or kind which had run out. There was no type-founder in America. Types had to come from London. Franklin had seen types cast in London, but had not paid much attention to the way in which it was done. He made metal moulds of the letters he wanted, although he does not tell very clearly how, and with these he seems to have pressed satisfactory letters out of cold lead. Later, he tried type-founding, but unsuccessfully.

Until 1836, all types were cast by hand. Then an American, David Bruce, Jr., of New York, patented the first type-casting machine, which did the work much faster. This machine had a small melting-pot filled with molten type-metal, and a pump forced enough of the metal into a type-mould to make a letter. This letter was quickly cooled, whereupon the mould opened, dropping it, and another letter was cast. Bruce's machine cast ragged types, which later had to be trimmed smooth by hand. It had been in use for fifty years when Henry Barth, of Cincinnati, in 1888, invented a machine that cast nicely finished types at the rate of 200 a minute. Just at the end of the nineteenth century an Englishman named Frederick Wicks invented a rotary type-casting machine which would turn out 60,000 types an hour, all perfectly finished and ready for the compositor. This great speed was made possible by using a hundred moulds instead of a single one, the moulds being rapidly filled with the hot type-metal, one after the other.

The moulds in which types are cast are themselves interesting. At first, they were simply plaster impressions of the letter to be made, but as type became smaller, and more of it was needed, the metal mould appeared. To make a type mould, a die-cutter first engraved the letter upon the end of a rod of steel. This was hardened, and called a "punch." The steel punch was then pressed into a block of copper, and that was the matrix in which the type was cast. Punches were made as far back as 1582, and probably earlier, in England and Europe. Cutting them was done secretly for many years, and one famous English type-founder, Joseph Jackson, in the eighteenth century, learned the art by watching his master through a hole bored in the wall of the workroom.

For printing small Bibles, die-cutters worked with a microscope on letters so small that, with type of the tiny "brilliant" size, twenty lines could be printed in an inch. A wonderful die-cutting machine invented by an American, L. B. Benton, in 1890, has cut the Lord's Prayer, sixty-five words, on a piece of metal one-sixth of an inch square—too small to print! It





(Left) OTTMAR MERGENTHALER, INVENTOR OF THE LINOTYPE.
(Right) ROTARY MATRIX LINOTYPE OF 1883.

This Mergenthaler machine, of 1883, was built in a dozen different types and proved moderately successful. Finger-keys controlled a rotary type-wheel with projecting characters. The characters were selected successively by the operation of the keyboard and indented in a papier-mâché strip. The matrix-strip thus formed was cut up into lengths and secured to a flat backing sheet in such a way as to form a page or column matrix. Type-metal was then cast into it and the plate obtained.

works upon the principle of the pantagraph, copying the actual-size letter wanted from a larger model. When dies were cut by hand, it took a year and a half to make all the letters for a new font of type, but with this machine the work can now be done, much more accurately, in five or six weeks. This machine appeared just at the time it was needed to cut the thousands and thousands of new punches made necessary by typesetting-machines.

Wanted—A Machine to Set Type

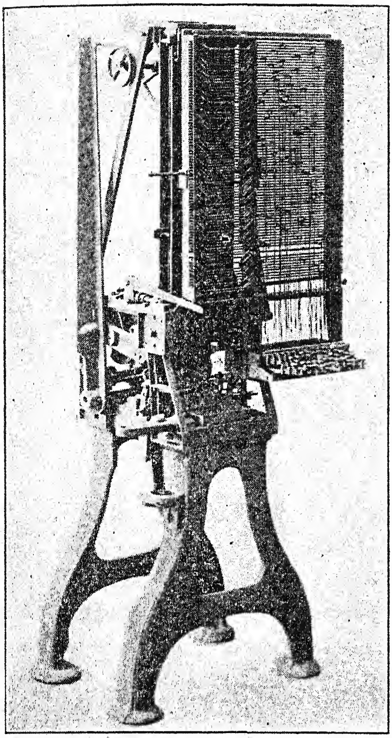
Until 1886, when Mergenthaler's linotype was first ready to use, all type was set by hand. Apparently no machine could do the work of the human compositor, picking out of the 150

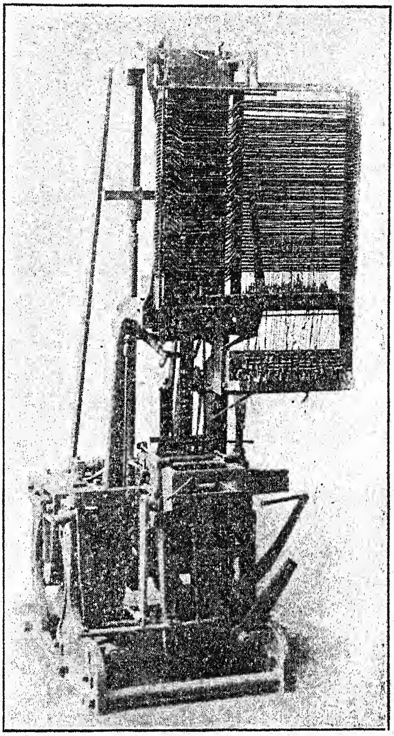
compartments of his "case" the different letters to make words, and lines, and "justifying" each line so that it would lock tightly in the form from which printing was done on the press. For that reason, the setting of type was the most expensive step in printing.

The inventors' first idea was to make a machine that would set printer's type—a good beginning, but a mechanical mistake. The first patent taken out for a mechanical typesetter was that of Doctor William Church, an American, who went to England in 1821 with a new printing-press, and in 1822 patented a machine that cast type and then set the letters one by one. It was not used very long. Other inventors tried to make machines that would set type, but not successfully. A machine called the "pianotype" was actually used in England in 1840, but the first typesetting-machine used to print a newspaper was that of Charles Kastenbein, a German, in England, whose machine, after several improvements, set the London *Times* about 1874—though it was not until 1879 that it fulfilled all promises. It was used as late as 1908.

Although these machines would really set type, all had the same shortcoming: they could not set it in lines as evenly justified as those of the hand compositor. Two machines were needed and three men. One man sat and played upon the keys of the typesetting-machine, and an endless line of type words, with spaces between, came out. A skilful compositor then set these words in a printer's "stick" by hand, and spaced the lines out evenly so that they would lock up. After printing, the type had to be distributed, ready to be set again. Distribution is also one of the handicaps of hand typesetting. It is a pretty sight to see the compositor's hand flying over his case, dropping or "distributing" letters in their proper boxes, so fast that the eye can scarcely see them. But, even so, it takes time to do this work. Hence the early inventors devised machines to set types, and other machines to distribute it after it had served its purpose.

Of this kind, the most wonderful typesetting-machine ever invented was the Paige compositor, devised by James W. Paige, of Hartford, Connecticut, who spent more than twenty years in perfecting it from 1873 on. Paige lost more than $1,300,000





(Left) THE FIRST MERGENTHALER BAND MACHINE.

This machine, of 1884, indented papier-mâché matrices of lines which were then assembled to form a stereotype matrix. It was equipped with a series of vertical bars, tapered endwise, each carrying a full alphabet of type and spaces. By means of finger-keys the bars were caused to descend successively, side by side, each being arrested to bring its selected character to a certain level. After the line of type was assembled and justified the papier-mâché matrix-strip was forced against it, thus producing the matrix for one line. These lines were then assembled side by side to form a stereotype matrix. A good impression was obtained, but the action was slow.

(Right) MERGENTHALER'S SECOND BAND MACHINE (1885).

This was the first machine to produce lines of type or printing-slugs automatically through the action of finger-keys. It was provided with a series of vertical tapered bars, each containing an alphabet of characters or matrices and blank spaces of different widths. Finger-keys caused these bars to descend one at a time, so that the selected characters, one on each bar, were brought to a common alignment. A sliding mould for the slug or line of type was presented against the line of matrices, and this mould was filled with molten metal from a metal pot at the rear, the matrices forming raised type on the front edge of the slug in the mould. The slug was ejected from the mould between trimming-knives into a galley. The matrix-bars were lifted to their original positions for a new arrangement of type. This was a practical machine but slow.

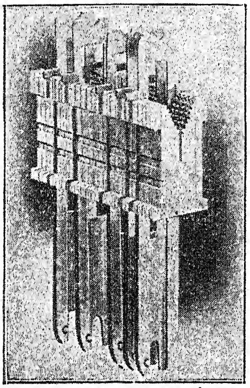
in trying to make it practical, and in 1921 entered a poorhouse near Chicago. Mark Twain, a printer by trade, believed so thoroughly in Paige's machine, that he also lost a fortune in aiding him. The machine was beautiful in operation, but too complex to work long without breaking down. It had 18,000 parts, and the patent specification in which it is described is a large book. Paige's machine set type in one endless line at first. Eventually, he succeeded in making it set justified lines, but never well enough for every-day work. All his machines set specially cast types, each type having a special combination of nicks in its edge so that it could drop into a groove with projections that fitted only its nicks. While type could be set with a Paige machine two or three times faster than by hand, it took three men to set, justify, and distribute it.

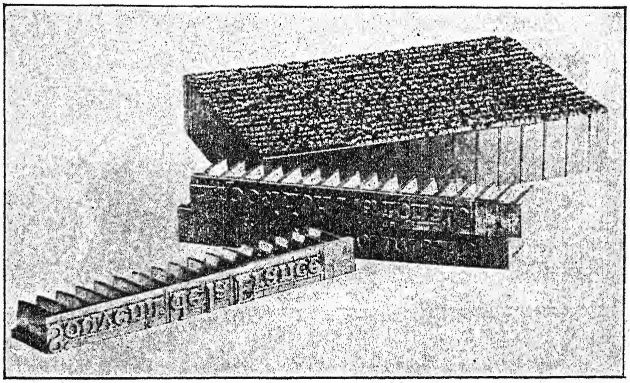
Presently, one or two inventors hit upon the principle found in the successful machines of to-day—the principle of making the machine cast its own new type, and so cheaply that when it has been printed from, it can be turned into the melting-pot, doing entirely away with the bother of distribution. What new type means is revealed by Benjamin Franklin's experience when he returned to Philadelphia. He had worked as a printer in London and, using new type, he started a printing-office of his own. Somebody advised him to get married, and even selected for him a girl, whom Franklin thought "very deserving." Her parents objected to him, saying printing was not a very profitable trade, that Franklin's type would soon be *worn out*, and that he would probably fail.

Not only did printer's type wear out, but when it did certain letters became scarce, and printers wasted time in looking for "sorts." Also, when a form containing new, partly worn, and badly worn type with broken letters was put on a printing-press, the pressman had to spend time "making ready," so that the type would print evenly. Often he brought the form back to have broken letters taken out. Since typesetting-machines, which are really type-casting machines, have been introduced, nine-tenths of all printing is done from new types.

THE TYPE-CASTING IDEA SOLVES THE PROBLEM

Best known of these inventors was Ottmar Mergenthaler, born in Württemberg, Germany, 1854. When eighteen years old he came to the United States. He had learned the machinist's trade in his native land and had been a diligent student in night and Sunday schools. Landing in Baltimore in 1872, he went to work for his cousin, August Hahl, who had a machine-





(Left) LINOTYPE MATRICES ASSEMBLED FOR CASTING.

A line of linotype matrices and spacebands as they appear before the mould in which the slug, or line-o-type is to be cast.

(Right) GROUP OF LINOTYPE SLUGS.

Large and small slugs composed on the same machine. Many different sizes and faces can be composed by the operator without the necessity of his leaving his seat at the keyboard.

shop in Washington, D. C. Hahl made instruments for the government departments. The United States Signal Service was then making weather observations, and young Ottmar became interested in building instruments for its scientists, work that involved invention. He soon became known for his quickness in grasping inventors' ideas, and from the scientific men for whom he worked he learned their way of approaching problems.

In the chapter on the typewriter in this volume, mention is made of James O. Clephane, a Washington court reporter, to whom Sholes and Densmore sent their writing-machines to be tested. Clephane found them all defective, and his criticisms

were severe. He was an official reporter for the United States Senate. His interest in the typewriter was practical, since he wished to find some better way of putting the voluminous Senate records in printed form. Several years after young Mergenthaler reached Washington, Clephane and a group of friends became interested in a writing-machine invented by a Virginian, Charles G. Moore. They put money into Moore's experiments. In 1876, when they were discouraged, they told him that unless he proved that his machine would actually write, they could not help him further. This led Moore to bring his writing-machine to August Hahl's machine-shop, which had been moved to Baltimore. Young Mergenthaler examined the apparatus. Moore thought it faulty in workmanship, but Mergenthaler said: "No—the fault is in the design." He was so sure the machine could be improved that he advised his cousin to undertake its perfection at his own risk. If Hahl could make it work, he was to get $1,600, and if not, he was to receive nothing. It was not really a printing-machine, for Moore wanted to write the Senate records on a keyboard like that of a typewriter, and print letters in lithographic ink on a paper ribbon. This ribbon was then to be cut into lines, made even by separating the words, as a printer justifies his line of type, and the lines transferred to a lithographic stone, to be printed.

Lithographic printing is different from type printing. The letters to be lithographed are drawn or stamped upon a flat stone with lithographic ink, which is oily. After having been treated with chemicals, the stone is put in a lithographic press, and dampened by water with the result that ink clings to the design, but not to other parts of the stone, so that it can be transferred to paper as in type printing. To harness the typewriter and lithographic press together and print Senate reports was a brilliant idea, but not practical. The lithographing was hard and caused endless trouble. The idea had been Clephane's, and when he saw that it would not work, he proposed another. Why not a machine that would press letters into a strip of *papier-mâché*, to make a mould into which type-metal could be poured? Why not use these cast letters for printing? Mergenthaler built such a machine, but even after a dozen changes it failed

to work. The *papier-mâché* strips clung to the cast metal, and there were other drawbacks. But the idea was sound—that of a machine which would cast type in a matrix, or mould.

Mergenthaler next built two machines in which whole alphabets of steel types were carried on bars or bands, so that a *papier-mâché* matrix for a whole word, and later, a whole line, could be cast at once. It was a little nearer, but not quite the right thing. Out of these machines, however, came the "big idea," namely separate metal matrices, each bearing the mould for a single letter, to be set in a line, like type, and metal poured in to make a solid printing line. Mergenthaler's first machine looked like a little church-organ, because it had a series of vertical tubes, each containing the matrices for a letter of the alphabet. By means of a keyboard the different letters were released. Because the matrices were blown into line by a blast of air, this machine was called the "blower." The principle proved correct, and 200 machines were made and sold. The first machine was set up in the composing-room of the New York *Tribune*, July, 1886, and the editor of that paper, Whitelaw Reid, gave it the name "lin-o-type." From that point on, the story of the linotype was one of improvement. Mergenthaler worked so hard that by 1894, when his linotype was setting type for hundreds of newspapers, his health broke down. A high-strung, sensitive man, never very strong, he became consumptive, and his last years, like those of Sholes, were spent in search of health. He died October 28, 1899, in Baltimore.

The other great invention in composing-machines was begun in 1885, just when Mergenthaler had built a successful linotype. Tolbert Lanston was the inventor. Born in 1844, at Troy, Ohio, he lived in that State and in Iowa until the Civil War, in which he served as a volunteer. In 1865, he became a clerk in the Pension Office, at Washington, D. C., and there he worked for twenty-two years, meanwhile studying law and being admitted to the bar. He had always been interested in mechanics, and at various times had invented an adding-machine, a mail lock, a hydraulic dumb-waiter, an adjustable horseshoe, and other things. When he turned his attention to a composing-machine, the idea of casting instead of setting

type had been proved correct. Lanston adopted it, and made two interesting modifications. First, a machine which would cast single types instead of a solid line of types, and second, a separate machine for casting the type, operated by a perforated paper ribbon, so that if the compositor at the keyboard were delayed, the composing-machine could run right along—a most interesting basic principle which has been utilized by many inventors.

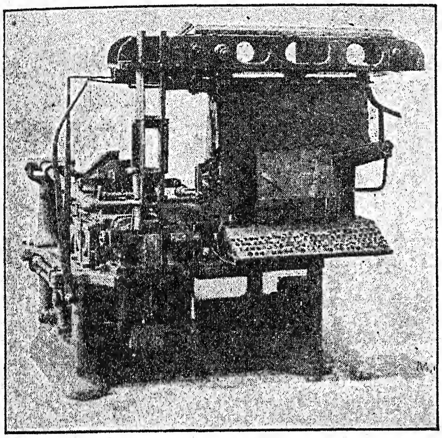
Lanston's first idea was to stamp types in cold metal. After five years' work along this line, he found it best to cast type from melted metal. His first patents were taken out in 1887, and ten years later, in 1897, the first machine was completed and given the name "monotype," meaning that it casts letters one by one instead of on the "lin-o-type" principle. Lanston died in Washington, February 18, 1913, after being stricken with paralysis, which made him an invalid in his last years.

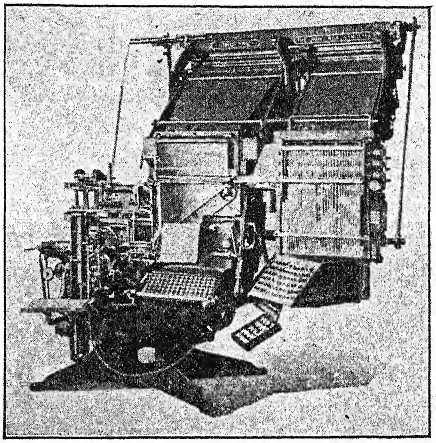
The monotype is really two machines. There is a keyboard that looks much like a large typewriter. The operator writes his "copy," and when each key is struck, two perforations are made in a paper ribbon. This perforated strip of paper is known as the "controller ribbon." The other part of the monotype is the casting-machine to which the controller ribbon is fed. As the ribbon runs through the casting-machine, air passes through its perforations; in an automatic piano this same process causes the right note to be struck; in the monotype it casts the right letters, one by one, at the rate of 150 a minute. As each type is cast it is pushed in a line, and each finished line is added to the last. It is therefore a typesetting-machine and also a type-foundry, making display types up to 36-point, or one-half inch, as well as body type, and so cheaply that, after printing, the type is not distributed but simply thrown back into the melting-pot.

Probably nine-tenths of all typesetting in this country to-day is done on either linotype or monotype machines, and these great American inventions are found in every country in the world. They are alike in casting brand-new type for each job of printing and in doing their work so cheaply that distribution is not necessary.

How Inventors Made Printing Plates

The type is set and locked up, ready for printing the page of a newspaper or a book. Gutenberg would simply have put the "form" on his press, printing from it directly. The world has progressed since his day. We have fast newspaper printing-machines, but none fast enough to print from one setting of type,





(Left) THE FIRST LINOTYPE TO SET TYPE FOR A NEWSPAPER.

Mergenthaler "blower" linotype first used by the New York *Tribune* in July, 1886. The machine was called a "blower" because the matrix was blown by a blast of air. About a hundred of these machines were built and installed in various newspaper-offices in the years 1887 and 1888.

(Right) THE LATEST MODEL LINOTYPE.

It sets type six times as fast as it can be set by hand. It has a range from five point to a full thirty-six point. Equipped with six magazines this machine has a capacity of six different body sizes, ten different faces, 850 different characters—all instantly available from the keyboard, and any combination of which can be assembled in the same line.

in two or three hours, the hundreds of thousands of copies needed for one edition of a present-day newspaper. Even if there were a machine to do it, the type would be worn out before the job could be finished. If a book is to be printed, later editions may be needed from time to time, and to store away the type for hundreds of books would take too much space and metal. More than one hundred years ago, printers felt the need of multiplying set type, and also to store away printing plates for books in the most compact and economical form.

Inventors have been busy meeting those needs for more than a century, and their inventions will be found in the stereotype and electrotype departments of the modern printing-plant.

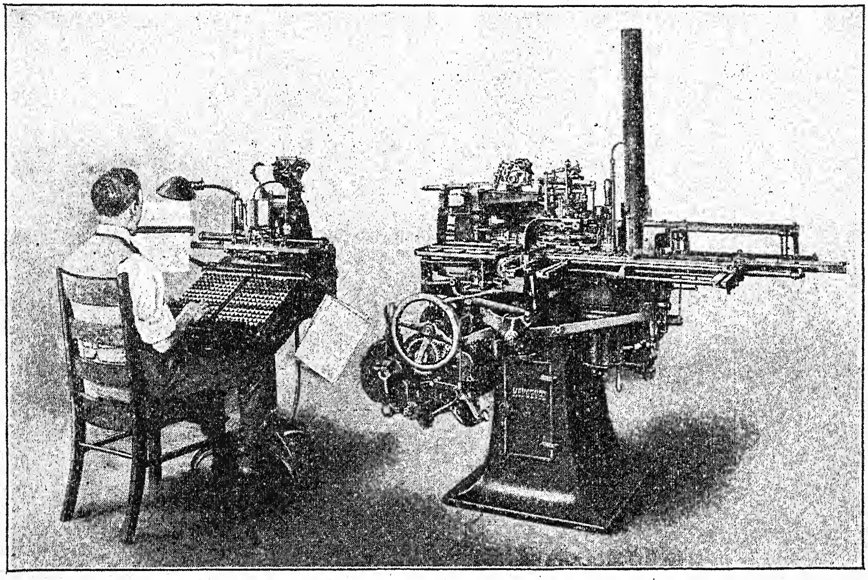
The early printers found that, with a little plaster of Paris, they could make a mould to cast as many types as were wanted. Some unknown genius conceived the idea of making a plaster mould of a whole page of type after it had been set up, and casting a plate to print from. This was the beginning of stereotyping. Solid printing-plates have been found dating back to the beginning of the sixteenth century, made, perhaps, by Van der Mey, a Dutch printer. But instead of casting plates in a plaster mould, he soldered types together after they were set, so that no letters would be lost.

In 1725, a Scotch goldsmith, William Ged, began lending money to printers, and learned that much of their capital was invested in type. Also, type had to come from London, and they often ran out of certain kinds. He was advised to start a type-foundry in Edinburgh. Instead, he got a form of type and began experimenting to discover if printing-plates could be made from it. After two years, during which he spent all his money, he succeeded in pouring liquid plaster over the type to make a mould, into which melted type-metal was then poured. Compositors feared that Ged's stereotype plates would rob them of work, and secretly battered them. This ruined the inventor, and he died poor. The idea lived, however. Two other Scotchmen, Alexander Tulloch and Andrew Fonlis, took out patents in 1784 for a better process. They cast their stereotype plates thin, as they are cast to-day, and fastened them to blocks of wood. Later still, the Earl of Stanhope improved the process, and stereotype plates became common. But because they were flat, they could be used only for the comparatively slow printing of books. Newspapers had to be printed faster than books. In 1813 David Bruce introduced stereotyping into the United States, the first work cast in America being the New Testament, in bourgeois type, in 1814.

Inventors had found that newspaper type pages could be locked rounded on the cylinder of a press, and as many as ten printing cylinders used. These ingenious "type-revolving" presses will be described later. But even then it was hard to

print from one set of type, in a few hours, as many newspapers as people wanted. Some way of printing on more than one press had to be found.

Only 3,000 or 4,000 copies of the famous London *Times* could be printed on one press in the second John Walter's day —he died in 1847. When there was important news, people



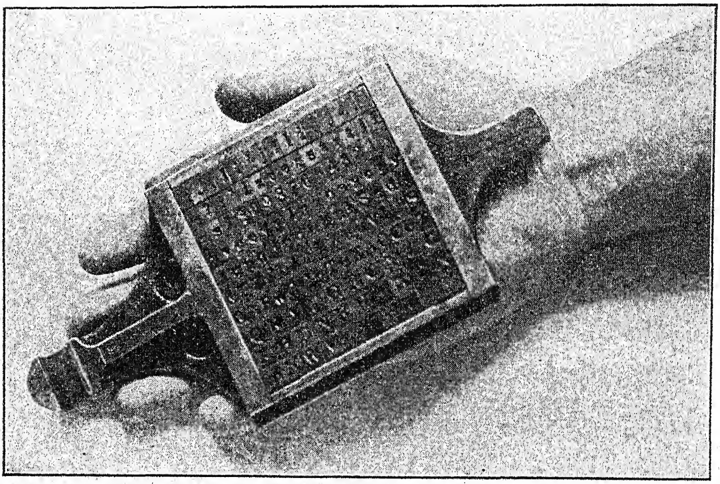
THE LANSTON MONOTYPE.

The Lanston monotype comprises two machines. On the one (that shown at the left) a keyboard is operated to perforate a paper ribbon. On the other (that shown on the right) the type is cast, the previously perforated ribbon being passed through it, after the manner made familiar by player-pianos.

wanted twice as many copies, but could not get them. Walter tried setting the *Times* twice, and even three times, to print more copies, but at a great cost. Suppose curved stereotype plates could be cast from one setting of the newspaper pages—as many presses as were needed could then be utilized. But how to cast such curved stereotype plates was a problem.

In 1856, the third John Walter began experiments, aided by an ingenious Italian named Dellagana. The *Times* was being printed on a curious Applegath press with separate columns of

type locked up on a polygonal, or many-angled cylinder, as will be described later. Walter and Dellagana found that *papier-mâché* (several layers of damp paper, with a facing of tissue-paper) could be pounded into type with a stiff brush, and dried in an oven. Thus a paper mould could be made in which printing plates could be cast. Flat plates of each column were first cast for the Applegath press, but that press was displaced



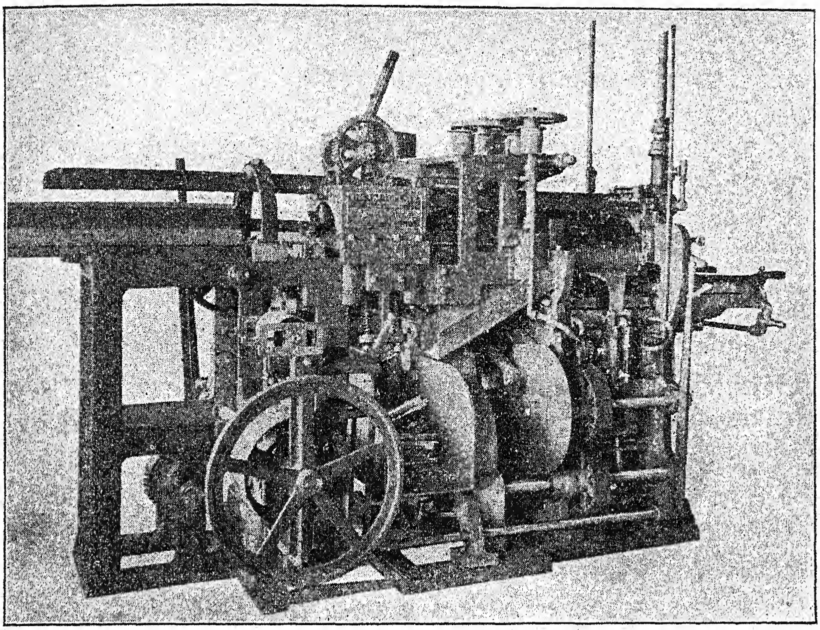
THE MONOTYPE MATRIX-CASE.

One hundred and fifty matrices constitute a complete change of type on the casting-machine. This case weighs only thirty ounces.

by one of American origin, one which printed from type locked around a cylinder. Walter and Dellagana found a way to cast a stereotype plate by making a *papier-mâché* mould of a whole page, bending it in a rounded casting-box and pouring in melted type-metal. Almost any number of plates could be made, and any number of presses supplied. In 1861, Charles Kraske, a New York engraver, working with the Hoes, the American press-builders, developed a method of casting curved stereotyped plates, and the New York *Tribune* first used them in this country.

Thus for nearly fifty years, stereotype plates for newspapers were all made by hand, although more and more of them were constantly needed. It was hot, heavy, slow work. In 1900, an

American, Henry A. Wise Wood, invented a machine to make the plates automatically—the autoplate. By hand it took a large crew of men two hours to make the many stereotype plates needed for a daily newspaper. To-day, with the autoplate, they can be cast in ten or fifteen minutes, with no hand-work



FIRST AUTOPLATE MACHINE OF HENRY A. WISE WOOD (1901).

By hand it took a crew of men two hours to make the many stereotype plates needed by an early newspaper. To-day, with the autoplate, they can be cast in ten or fifteen minutes.

beyond the pulling of control levers. The autoplate is really two machines, a mechanism that casts seven or eight plates a minute, and another machine that trims off rough edges so that the plates fit and print perfectly. Newspaper columns can now be held longer for final news reports, and big, complex, costly presses begin to turn sooner than would otherwise be possible.

When Wood's first stereotyping-machine was finished, the newspaper publisher who had ordered it feared the opposition of his stereotypers. To sell his machine, the inventor undertook

to deal with the stereotypers. He showed them the machine doing their work automatically, and told them that, while it might displace some of them at first, in the end it would make more work. He also reminded them that workers had never successfully opposed machines. They offered to work with him, even to guard the machine against accidental or deliberate damage. Their labor organization really adopted the machine, the first time, it is said, anything like this was ever done. The autoplate is now used all over the world. There has been only one strike against it, in Europe, which the inventor quickly settled. And it has increased work, as he said it would, for there are two or three times as many stereotypers employed in newspaper plants to-day, because the machine has made it possible for newspapers to grow in size and circulation.

The Electric Battery and Printed Pictures

Electricity also makes many printing-plates from one set of type. Books and pictures have always gone together. Picture-writing came before alphabetic letters. Hand-written books (manuscripts) were often ornamented with pictures. When movable types made books more plentiful, printers soon found a way of illustrating them with pictures. The picture was drawn on a block of wood, and the "high lights" were cut out, leaving the shadows and lines raised for printing. This was "wood-engraving," and most of the pictures in books, magazines, and newspapers were illustrated with such engravings until photo-engravings began to be used. At first, these "wood-cuts" were small and crude, but they steadily improved. Great artists often drew the pictures and even did the engraving themselves. Finer tools were made for cutting. Better wood was found. Machines were invented to save the engraver work by automatically cutting ornamental patterns and shading.

But some way was needed to multiply wood-cuts. It was too expensive to cut more than one block. If used for printing, the block soon wore out; besides it was often damaged. Stereotyping could not copy the most delicate lines in a fine wood-engraving; moreover, the stereotype mould was made with wet material, and that spoiled a wood-engraving by warping it.

Suddenly this problem was solved in an unexpected way. Several men hit upon the same idea about the same time—something that seems to happen frequently in invention. Probably the foremost was a Russian professor, named Jacobi; but there were several Englishmen, among them Bessemer, who afterward invented the steel converter. Then J. C. Jordan, a Londoner, announced his invention within a few days of Jacobi, in 1839. They all discovered that the electric battery could be employed to make "electrotype" copies of wood-engravings.

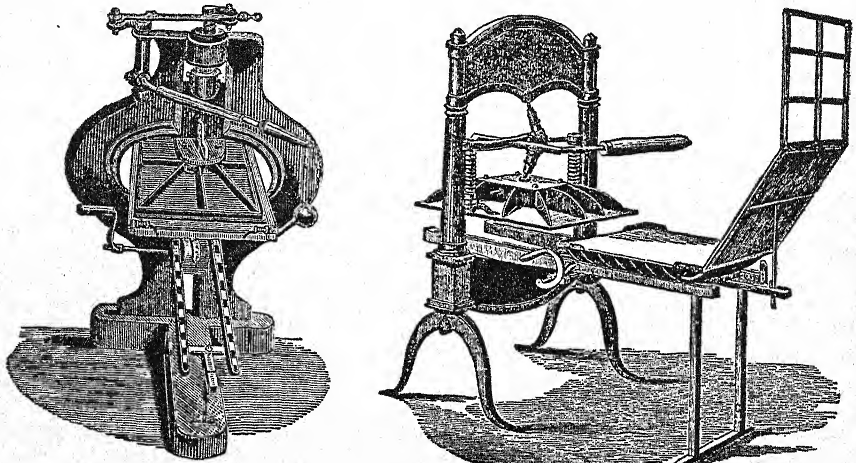
The electrotype is a first cousin of the silver-plated spoon. These early inventors found that a coin or metal could be impressed in wax, and the impression dusted with graphite powder to make it conduct electricity; this was then used to gather a film of electrically deposited copper, which faithfully copied every detail. The process was soon widely used for making duplicates of wood-engravings, as well as pages of type for the finer printing needed in books. The thin copper shell was too frail for a printing-plate, but when backed with molten type-metal and mounted on a wooden block, it could be used to make thousands, and often millions, of impressions, whereas a wood-engraving would be worn down to a stump. The electrotype process is used to reproduce each type page of a book on a thin plate and to store the plate so that it can be used again and again.

Improving Gutenberg's Wooden Cheese-Press

Although a job of printing reaches the press-room last, it was the press that first interested inventors—probably because printing on the early hand-presses was so slow and hard.

Gutenberg, and Coster, and printers who came after them for 170 years, had crude wood-screw presses of the kind that had long been used for pressing cheese and wine grapes. The type was placed on a flat table or "bed," and inked, and then a sheet of paper laid upon it. Type and paper were pushed under a "platen," or flat surface, and this platen was screwed down from above to squeeze the paper upon the type. Nobody made any better press until about the time the Pilgrims arrived

at Plymouth Rock. Willem Janszoon Blaeu, of Amsterdam, Holland (born 1571, died 1638), built a better wooden press. He steadied the wabbly platen by passing the screw through a small block which was guided in the wooden frame and by suspending the platen from this block. Hence, the screw worked more smoothly. Blaeu also lightened the labor of running the type pages in and out of the press. His press, copied by others,



Courtesy R. Hoe & Co.

(Left) STANHOPE PRESS (1800).

About 1798 the Earl of Stanhope improved the old hand-press by giving it a cast-iron frame, the necessity for greater power having arisen, a necessity which could not be met by the old wooden-frame presses.

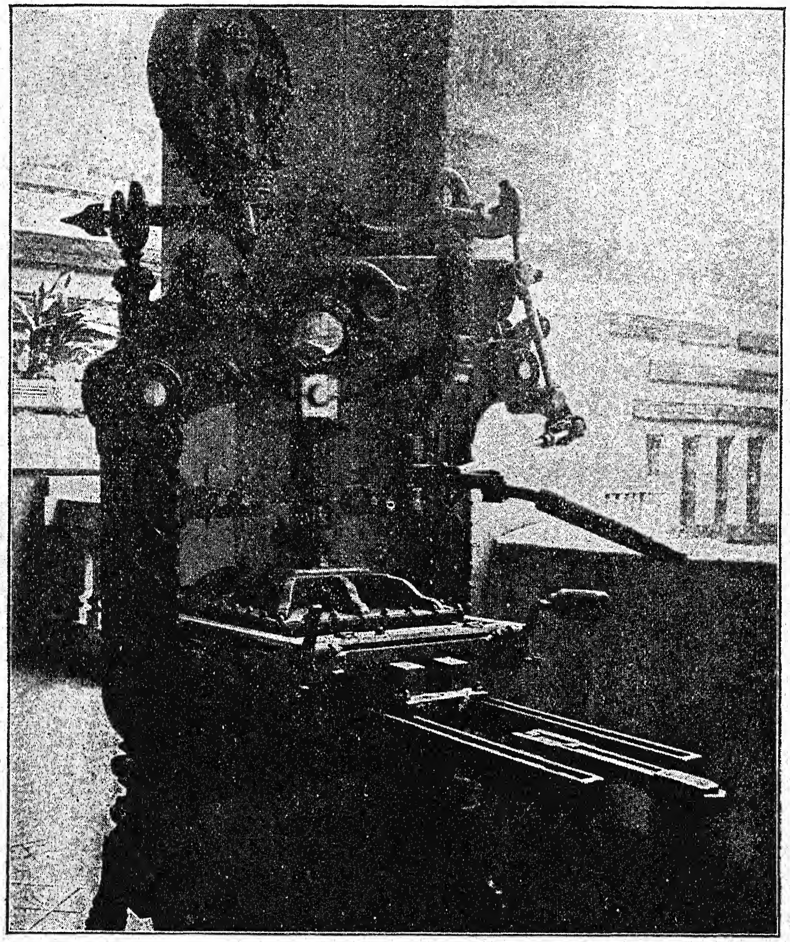
(Right) PETER SMITH'S PRESS (1822).

In place of the screw with levers Smith substituted a toggle-joint, at once very simple and effective.

soon became known as the "new-fashion" press. Benjamin Franklin worked with a press like Blaeu's in London more than a century later, and it is now in the Smithsonian Institution at Washington.

The Earl of Stanhope made a hand-press of iron in 1798. This was more powerful, and it printed larger pages. Even Blaeu's "new-fashion" press required the strength of a plough-

man, but Stanhope lightened this work by a combination of levers that helped the pressman considerably. Heavy and cumbersome as it was, this was the first iron printing-press ever



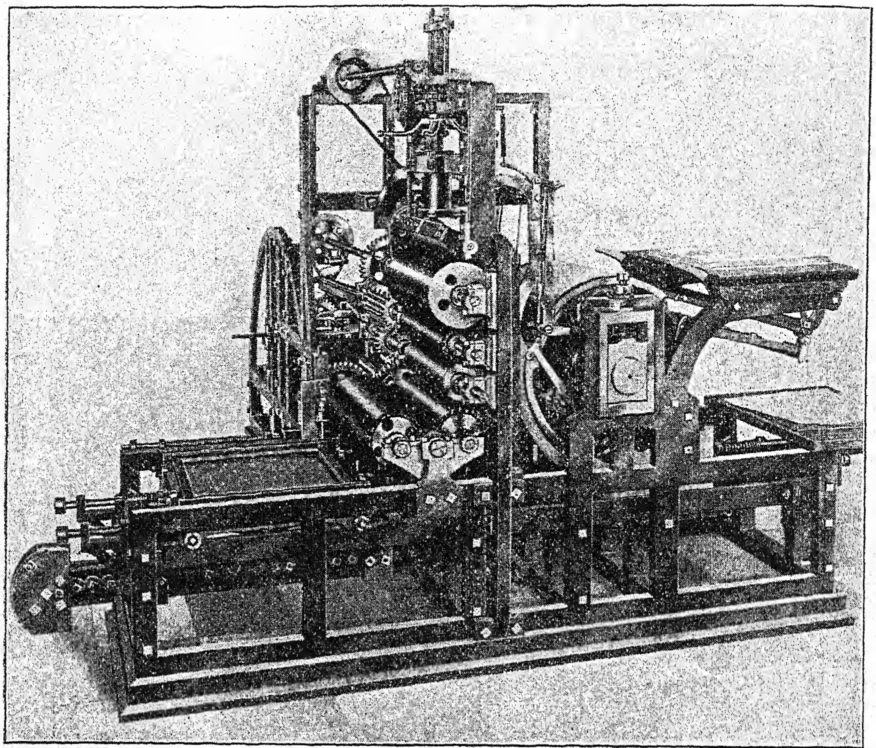
THE COLUMBIAN HAND-PRESS.

The inventor was an American, George Clymer (1754–1834). This specimen, made in 1824, is preserved in the Museum of Brunswick, Germany.

made. Printers tried to use Stanhope's powerful lever on their old wooden presses, but it was so strong that it broke them to pieces.

Then an American, George Clymer, of Philadelphia, in 1816,

invented an iron hand-press without a screw, using a combination of three levers instead. This was the first real American invention in printing. He put a cast-iron American eagle on top of his press and called it the "Columbian." It was a very



Courtesy Deutsches Museum, Munich.

FRIEDRICH KOENIG'S FIRST RAPID STEAM PRINTING-PRESS OF 1811.

Koenig presses of this type were first used to print the London *Times*. They were introduced only after great opposition on the part of the paper's pressmen.

powerful machine for those days. The iron eagle was more than an ornament, for it helped to lift the platen, after printing, by serving as a counterweight. Clymer's press enabled printers to work still faster; and it marked the beginning of a hundred years' printing progress in which Americans were to lead.

Inventors kept on improving Gutenberg's cheese-squeezer up to 1827, when an American, Samuel Rust, of New York, perfected

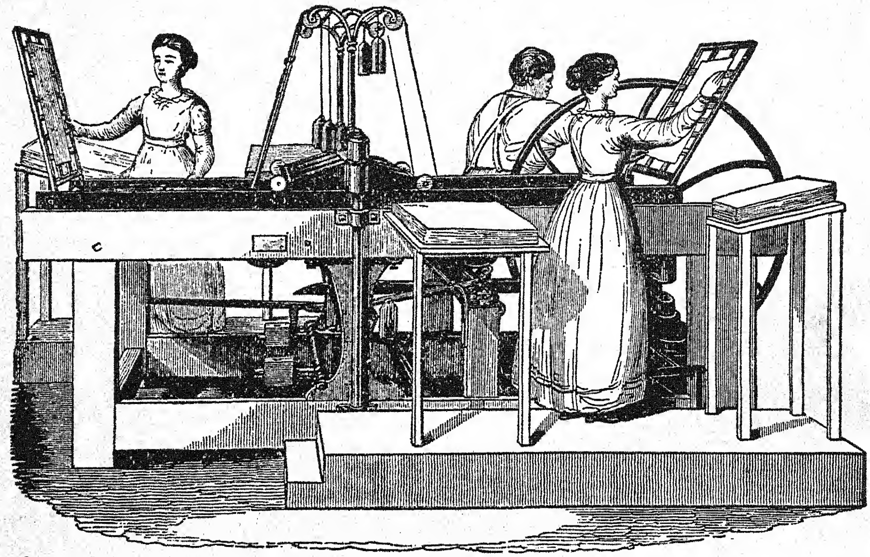
the Washington hand-press, still used to strike off fine proofs, and still known by that name. With the press that Franklin and printers long after him used, 250 impressions an hour was fast work. Inventors made little progress until they rid themselves of the old "press" idea. The great newspaper printing-machine of to-day is still called a "press," but it is no more a press than a locomotive is an "iron horse." In the hand-press the type was always rolled out for inking, and then rolled back for printing. Why not ink it with rollers? Why not roll the paper too? Inventors began to ask themselves these questions. Even the idea of unwinding a great roll of paper and printing on that, as we print newspapers, magazines, and books to-day, was suggested early in the nineteenth century by Sir Rowland Hill, although he did not build a machine to carry out the idea. He was the Englishman who later made possible the sending of a letter for two cents anywhere in the British Isles.

The Steam-Engine Is Hitched to the Printing-Press

The first printing-machine that rolled the type, ink, and paper was invented by a German, Friedrich Koenig (born 1774, died 1833), the "Father of Steam Printing." He built a press in which the type was laid on a flat bed, inked by rollers, and passed underneath a cylinder that rolled the paper upon it, to receive an impression. He built several such cylinder presses to be turned by hand. In 1814 he constructed two, turned by a steam-engine, which were used for printing the famous London *Times*, a newspaper whose publishers, the Walter family, seemed always ready to encourage inventors who came to them with good ideas. As we have seen, this newspaper was the first to use typesetting-machines.

Koenig had gone from town to town in Germany, trying to get help in building a press on his new lines, but nobody would listen to him. So he went to England, owning nothing but his idea, and worked at the printing trade for a living. Three years passed before he could afford to build a model of his invention, and several models were built before he undertook to make a full-sized newspaper press. There was great excitement

among the *Times* pressmen when they heard that a machine was being made to do their work! The parts were taken to the newspaper-office and assembled secretly. The men threatened violence both to Koenig and to his machine. On the first night when the press was ready for work (November 28, 1814) the pressmen were told to wait, because important news was



Courtesy R. Hoe & Co.

TREADWELL PRESS OF 1822.

The bed-and-platen system of printing was, up to the middle of the nineteenth century, the favorite method of printing fine books and cuts. The first "power" or steam-press upon this principle was made by Daniel Treadwell of Boston, in 1822.

expected from abroad. They waited until six o'clock in the morning. Then John Walter suddenly appeared with copies of the paper, saying: "The *Times* is already printed by steam!" He added that wages would be paid to every one of them until they had found other places. There was no further trouble.

In a sense, Napoleon did as much as Gutenberg to develop printing, because he was a news-maker. During the twenty years, from 1795 to 1815, when he was fighting all Europe, people wanted to know where the world stood each morning, and

newspapers could not be printed fast enough. Koenig was working to keep pace with the demand, and when he came forth with his steam cylinder press, the proprietor of the London *Times* encouraged him.

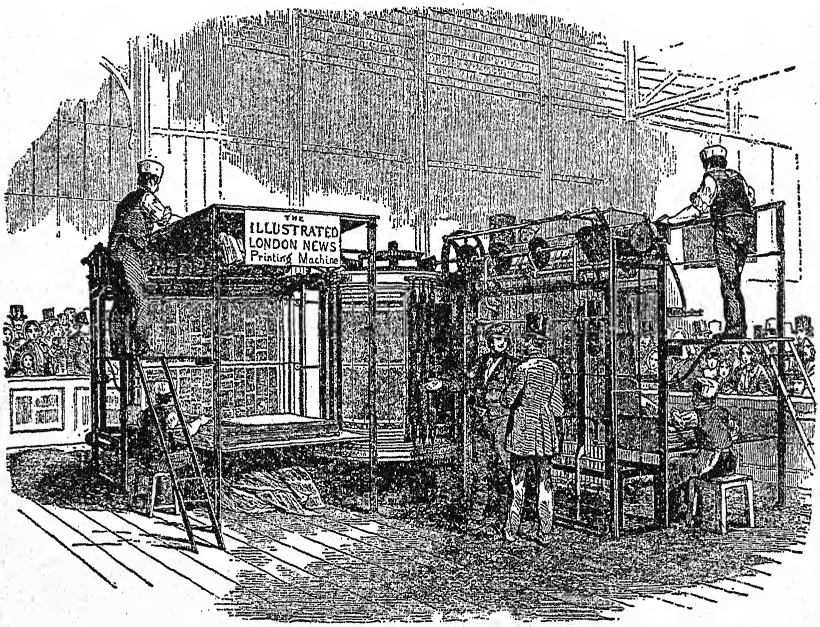
Koenig's press could print on only one side of the sheet at a time. Hence it had to be run through twice to be printed on both sides. But it was a great step forward, and inventors busied themselves with his cylinder principle. Because news-hunger was greatest in Europe, English inventors led the world in printing-presses for thirty years. As early as 1790, an Englishman named William Nicholson had taken out a patent for cylinder presses in which the type was placed either on a flat bed, like Koenig's, or on the cylinder itself, the type being inked by a roller built up of cloth and covered with leather. He was far ahead of his time and other inventors had to carry out his principle years later.

Inventors did not give up the principle of the "platen" press that squeezed the paper upon the type like the old hand-press. Bed-and-platen presses were invented, too, and an American, Daniel Treadwell, of Boston, built a press of that kind in 1822. The first was turned by a man; the rest by steam. Instead of squeezing the platen down on the type, as in the hand-press, the type was rolled under a fixed platen, and squeezed up against it. Isaac Adams and Otis Tufts, both Bostonians, invented an improved platen-and-bed press between 1830 and 1836, and such machines were in common use up to the middle of the nineteenth century. They were somewhat cheaper than cylinder presses, and small printers could afford them. At that time, many printers thought they could print only fine book-work and engravings with flat presses.

A Young Carpenter Starts a Famous Printing-Press Family

Leadership in printing-press invention swung to the United States between 1830 and 1840, and has been held here ever since, although the man who did most to make American printing-presses known in every country on the globe was English by birth. He landed in New York in September, 1803, looking for

work. His name was Robert Hoe, the first press builder in a famous printing-press family, and he came from Leicestershire, England, where he was born, October 29, 1784. A country lad, he had learned the carpenter's trade. When he landed, the



THE APPLEGATH PRESS OF THE LONDON *TIMES* (1848).

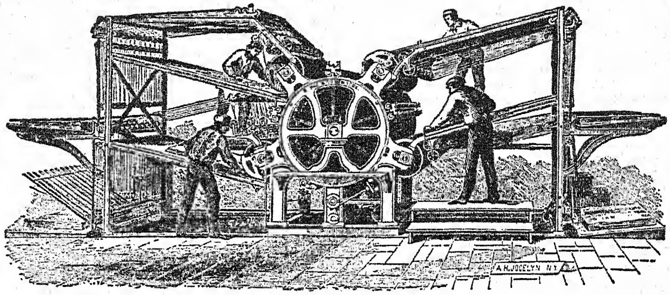
Applegath and a machinist named Cowper simplified the Koenig press. In 1848 they constructed for the London *Times* an elaborate machine entirely on the cylinder principle. All the cylinders were vertical. The type was placed on a large upright central cylinder, but the circumference presented, instead of a complete circle, as many flat surfaces as there were columns in the newspaper, the form being therefore polygonal. Around this central cylinder were grouped eight smaller vertical cylinders, which took the impression. The sheets were fed down by hand from eight flat horizontal feed boards through tapes; then grasped by another set of tapes and passed sidewise between the impression-cylinder and the type-cylinder. Thus the sheets were printed upon one side. The speed was 8,000 impressions per hour on one side.

dreaded yellow fever raged in New York, then a city of only 25,000 people, deserted by everybody who could fly from the epidemic. After walking penniless through the plague-stricken city, keeping in the middle of the street to avoid catching the fever, he applied for work to a seedsman, Grant Thorburn, in lower Broadway. Thorburn liked his honest English face, and

took him in to board. Within a week Hoe had the fever, and would have died had not the seedsman and his wife nursed him. When Hoe was well again he obtained a position as a bridge-builder in Westchester County, and later met and married a sister of Matthew Smith, Jr., a carpenter and "printer's joiner," who built type-cases and hand-presses. Matthew's brother Peter, in 1822, became the inventor of a better hand-press than had been made up to that time. Robert Hoe went into partnership with the Smiths.

Cast iron as a substitute for wood was just coming into use for hand-presses. Hoe not only learned to work in iron, but invented the first machine for planing iron ever built in this country, and also imported iron-working machinery from England. Until 1823, when Matthew Smith, Jr., died, the firm built printing-presses and printers' supplies. Then Hoe took charge of the business. About 1819 he began building power-presses, but at first he was not very successful. When Treadwell's platen-and-bed press appeared in 1822, he saw its merits and adopted it. For three or four years it stood without a rival in this country.

Then two New York newspapers, the *Daily Advertiser* and *American*, imported from England the first cylinder press ever used in the United States, an ingenious invention, patented by Napier, an Englishman, who first introduced the "grippers" or fingers that grasp the edge of a sheet of paper to carry it around for printing on a cylinder press. Up to that time the paper had been drawn in by tapes, working like belts, which was not as satisfactory. Several years later, in 1829 or 1830, the *National Intelligencer*, a Washington newspaper, imported another Napier cylinder press from England, but its publisher, having lost money, was unable to take it out of the customs house. Major Noah, the surveyor of the port, called in Robert Hoe to assemble it, and let him make models of its parts. This press had to be shipped back to Europe, because nobody would pay the duty on it. Hoe saw that it was far better than anything then known in the United States, and he began building presses like it. His shop grew into a factory, with four big English draft-horses to furnish the power, although eventually he was one of the first American manufacturers to install an engine. In 1832, Eng-

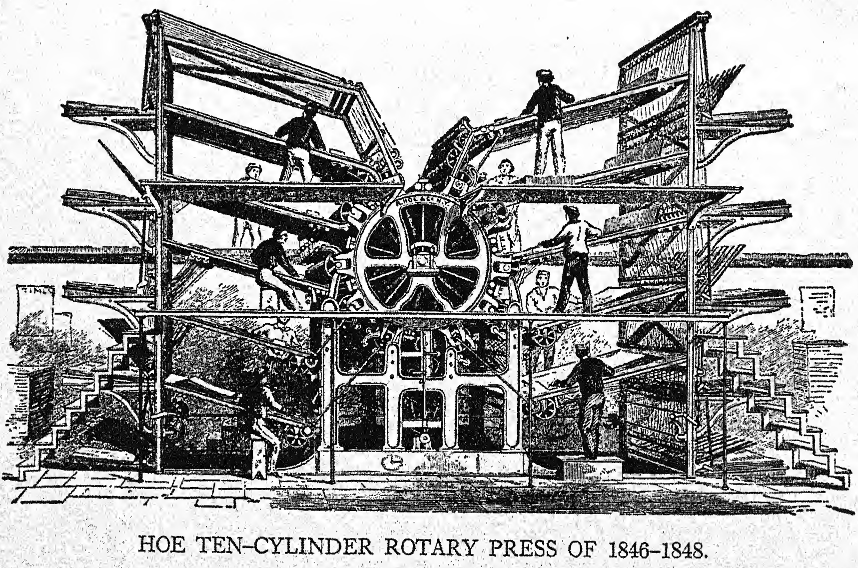


(Left) RICHARD MARCH HOE (1812–1886).

The son of Robert Hoe, who invented the system of placing the type on a revolving cylinder.

(Right) HOE PRESS OF 1846.

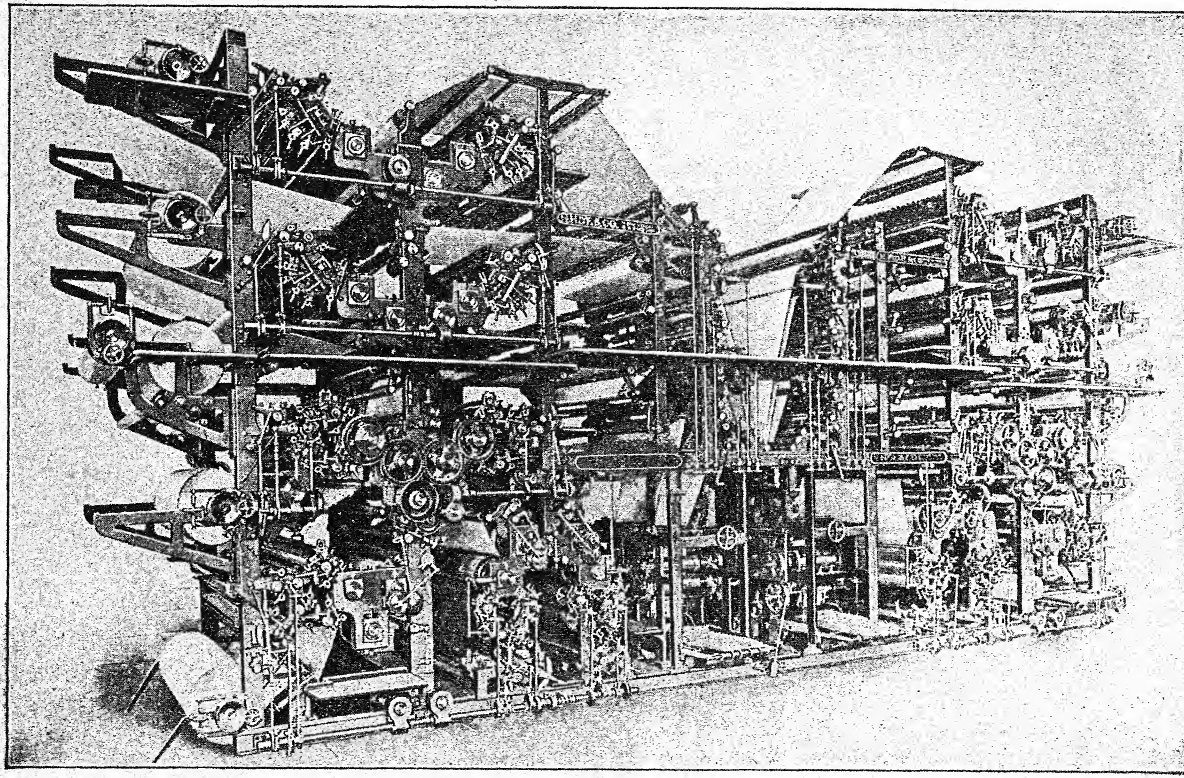
The first press was placed in the *Ledger* office in Philadelphia, in 1846. The basis of Hoe's invention consisted in an apparatus for securely fastening the forms of type on central cylinder, placed in a horizontal position. Around this central cylinder from four to ten impression-cylinders, according to the output required, were grouped. The first of these presses had only four impression-cylinders, and required four boys to feed the sheets. The running speed was about 2,000 sheets to each feeder per hour, thus giving what was called a "four-feeder" or "four-cylinder" machine a running capacity of 8,000 papers per hour, printed on one side. (See ten-grouped-cylinder-press development, below.)



HOE TEN-CYLINDER ROTARY PRESS OF 1846–1848.

Capacity, 20,000 pages per hour, printed on one side. Journals which had been limited in their circulation by their inability to furnish papers rapidly increased their issues.

About 1856 the London *Times* decided to discard its famous Applegath machines and ordered from Hoe two ten-cylinder machines.



MODERN HOE DOUBLE PRESS FOR FAST NEWSPAPER PRINTING.

lish cylinder presses had become so famous that he sent his foreman, Sereno Newton, to England to study them. Newton was a very fine machinist, as well as a scholar and mathematician. He came back with new ideas, and invented a cylinder press so much better than any of the English machines then used in this country that they were soon displaced. Robert Hoe was so energetic that he would go without lunch, and sometimes without breakfast, to have more time for work. On January 4, 1833, he died, in his forty-ninth year, broken down by overwork, and left the business to his three sons, Richard March Hoe, the second Robert Hoe, and Peter Smith Hoe.

Richard and Robert became the leaders, and the former the Hoe family's greatest inventor. The three would dispute with vigor about matters of management, and then always act together. They did everything together, even to buying and using one carriage. Richard made improvements in his cylinder presses, yet the demand for news grew and grew, and no matter how fast presses ran they could not keep up with it. When the type from which a newspaper was printed had been set up, there was in those days no way of making duplicate plates by the stereotype process. With stereotype plates as many presses can be utilized as are needed, but with type all the printing had to be done on one press.

The Beginning of the Modern Rotary Press

One evening in the year 1846, Richard Hoe was thinking about this handicap when an idea flashed in his mind. The type for a newspaper page was locked up in a "chase," or iron frame, and laid flat on the bed of the press, where it rolled back and forth, and a cylinder rolled the paper over it sheet by sheet. Suppose the type were fastened around the cylinder instead, and the paper rolled against it—would not that mean twice as many copies an hour? He sat up all night working out his idea, and a few days later told an editor about his scheme for a "lightning" press. He was given an order for such a press, obtained a patent in July, 1847, and built a printing-machine in which the type was locked up in curved chases, fastened on a large cylinder; two smaller cylinders, carrying sheets of paper,

rolled against it for printing. To lock the type in a curve, he had hit upon the principle of the wedge-shaped keystone by which square stones can be built into an arch. That is, he used the brass rules between the columns of a newspaper for keystones, making them wider at the top than they were at the bottom. This was the "type-revolving" press, a new principle that later led to the rotary press.

Where 1,000 newspapers an hour had been fast work for the best cylinder presses, this machine printed 2,000. It was quickly followed by another having four printing cylinders, turning out 4,000 papers an hour. Then came one with six cylinders in 1852, one with eight, and finally a ten-cylinder press in 1855, which printed 10,000 complete newspapers hourly, and for nearly twenty years was the champion press of the world.

Almost at the same time, in 1848, Augustus Applegath, an Englishman, perfected a "type-revolving" press for the London *Times*, after much experiment. This was a novel machine. It had a large vertical cylinder upon which the type was placed, not in a true circle, as in Hoe's press—which had a horizontal cylinder—but with each column of the newspaper in a flat upright bed. Hence the printing surface was not a cylinder but a polygon. Eight "cylinders," carrying sheets of paper, printed against this many-sided arrangement of type. They had to be covered with special blankets to make up for the irregularity of of the printing surface. The sheets of paper were fed in horizontally by hand, and a system of tapes turned them upright for printing. It was an ingenious, but very complex press, printing only 8,000 sheets an hour, on one side. Just one Applegath press was ever built, it is said, as Richard Hoe's rotary press soon displaced it. Some think Applegath the first inventor of a type-revolving press, but Hoe's was certainly better.

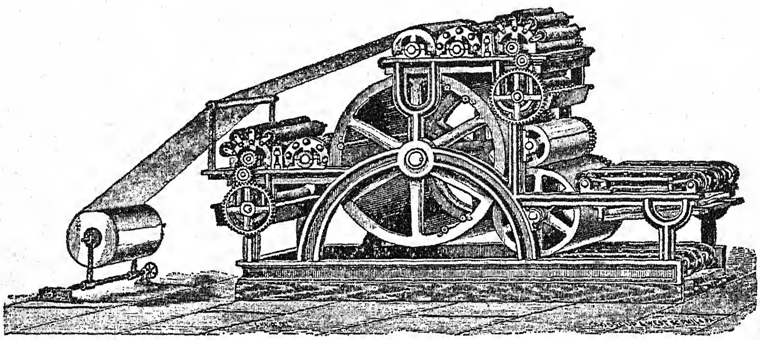
Ten thousand newspapers an hour were not enough! People wanted more newspapers than could be printed on a single press, no matter how many cylinders were used. To use more presses, each newspaper would have to be duplicated in type for each press, and that was too costly. Our Civil War had just started. Think of the desire for news it brought!

The problem was solved with two new inventions. One

was the curved stereotype plate, already described, and the other the use of a continuous roll of paper instead of single sheets fed by hand.

Printing Newspapers by the Mile Instead of the Page

Sir Rowland Hill had suggested this forty years before, but had made no machine to do it, nor had anybody else. An



BULLOCK'S PRESS—THE FIRST TO PRINT FROM A WEB.

In 1865 William Bullock, of Philadelphia, constructed the first press which printed from a continuous web or roll. His press had two pairs of cylinders—two form or plate cylinders, and two impression-cylinders. The sheets were cut off by knives in cylinders. The sheets were then carried through the press by tapes and fingers, and delivered by automatic nippers placed on endless leather belts at such distances apart as to grasp each successively as it came from the last printing cylinders.

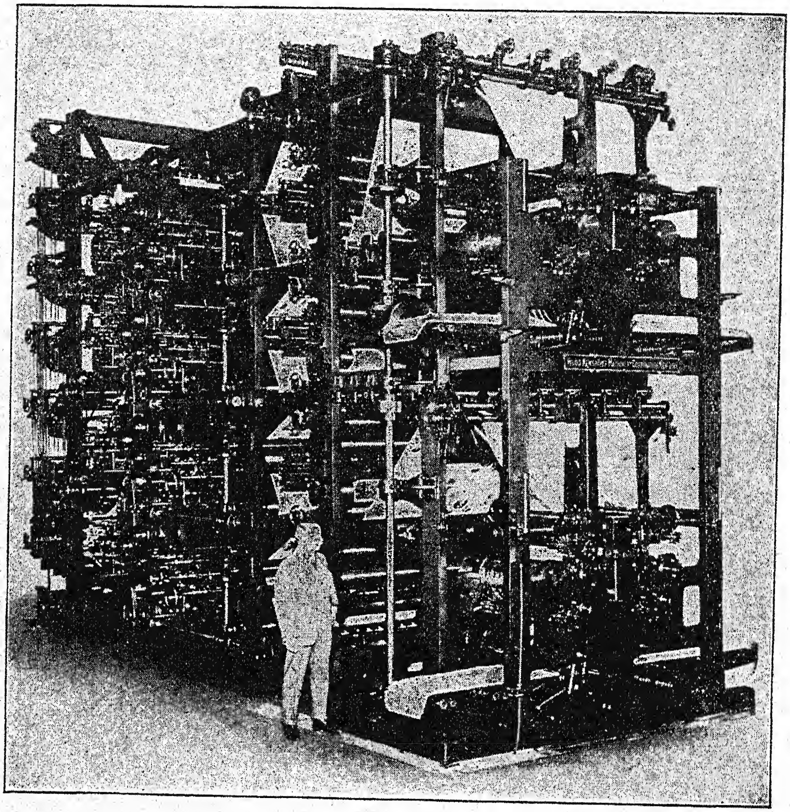
American, William Bullock, of Philadelphia, in 1865, built the first machine to print from a continuous roll or "web" of paper. This was set up to print the New York *Sun;* it is said to have been the first American press especially built for curved stereotype plates, although by that time the Hoe brothers were also working toward the same end. The third generation of that family was now active in the business. Richard March Hoe died in 1886. His brother, the second Robert Hoe, outlived him. The third Robert Hoe, born in 1839, lived until 1909, and was among the inventors who built perfecting presses for magazine and color work, as well as being a famous collector of books on the art of printing. The business is now managed by the fourth generation.

Bullock did not live long enough to perfect his press, for he was caught in a belt and accidentally killed. His machine was a long step forward, but he made a mistake that would surely have been corrected had he lived. His press cut the web of paper into separate sheets *before* printing, instead of *afterward*. Therefore it had to have metal grippers and tapes which often got out of order in the rush of printing newspapers. In 1871, the Hoes undertook to correct this and other shortcomings in their first "rotary" presses, as they were called. For one thing, the paper was printed by Bullock's press so rapidly on one side and then the other that it smudged. That was remedied by the Hoes partly by improving the press and partly by the use of rapid-drying inks. It was hard to obtain the cheap paper received by newspapers in rolls of even strength and quality. Paper-makers were led to study and improve their product. Cutting the papers off the roll after printing was the right way, but there were difficulties. Chopping off separate papers was like chopping the belt that runs a machine, since the paper was drawn through the press like a belt. This the Hoes overcame by perforating instead of cutting the paper, and pulling the finished newspapers apart after they had passed out of the press. These perforations can be seen on the edge of almost any newspaper to-day.

After movable types, the next greatest single invention was rotary printing, according to some of the newspaper press builders. And after that, folding mechanism was the invention that did most to increase the output of newspapers. At first, the printed sheets were taken from the press one by one and folded by hand. In 1877, Richard March Hoe and Stephen D. Tucker patented the "collecting cylinder," by which a number of printed sheets of paper were collected and delivered together, thereby greatly increasing the output of the press. Then an odd genius named Luther C. Crowell appeared. He was a sea captain, with no mechanical training, who, after he retired, invented a machine to fold paper bags. Being told that folding the newspapers from fast rotary presses was a problem, he looked into it and found methods of folding and taking them away as fast as they were printed.

Newspapers began to increase in size from four pages to

eight, twelve, sixteen, and more. Moreover, an eight or twelve page paper might be large enough one day in the week, while the next day sixteen or twenty-four pages might be needed to



HENRY A. WISE WOOD'S PRESS FOR NEWSPAPERS.

This press prints 240,000 eight-page papers an hour. In the fast presses previously used the paper was pulled through. Hence the speed attainable was limited by the tensile strength of the paper. In this new press the paper is carried through, so that the speed is no longer limited by the resistance of the paper to breaking.

print all the news and advertisements. Consequently, rotary presses were not only made larger, but in "multiple" combinations.

The curved stereotype plate of a newspaper page is a half circle. Two such pages are locked on a rotary-press cylinder. Each cylinder is made wide enough to hold two pairs of plates,

or four pages, and two such cylinders, to print eight pages, are known as a "couple." A press with four such couples was built to take two separate rolls of paper. Called a "quadruple" or "quad" for short, it could be used to print newspapers of four, six, eight, ten, twelve, fourteen, or sixteen pages, as desired, cut and folded for delivery, and even counted, as each fiftieth paper was slightly raised above the others to serve as a marker. This led to sextuple presses, also printing eighteen, twenty, and twenty-four page papers; then came octuple presses, with eight printing couples using four webs of paper, turning out sixteen-page newspapers at a greater rate, and printing twenty-six, twenty-eight, thirty, and thirty-two page newspapers. Even larger than these are the double-sextuple and double-octuple machines.

Newspaper presses had grown so big and fast that just about 1914, when the Great War made the world more eager than ever for news, they had reached the limit of the strength of paper; that is, they could print paper faster than it could be pulled through without breaking; for the paper was used as a belt. Henry A. Wise Wood undertook to overcome this difficulty by building a press in which the paper would be *carried* through instead of *pulled* through, making it possible to run it faster without breaking. His first press was set up in the office of the Philadelphia *Evening Bulletin* in 1917, printing 120,000 sixteen-page papers an hour, or more than twenty-five times as many daily newspapers as were read in all the United States a hundred years ago, remembering that newspapers then usually had only four pages. At such speeds ordinary printers' rollers proved unsuitable. Printers' rollers were made of glue-and-molasses composition, and were a wonderful invention in their day, but rollers of a rubber composition were needed for such speeds. It may be that newspapers cannot be printed much faster, but it has been predicted that within the next few years sixty-four-page newspapers will be turned out at the rate of 100,000 hourly.

There are other kinds of printing that need their own variety of presses. Magazines, for instance, cannot be printed on newspaper presses. The newspaper is printed on absorbent "print" paper, so that the ink does not smear. Magazines that are

printed on smooth "coated" paper with better ink that does not dry as quickly, and those using fine illustrations, need their own special presses. The cover of a magazine in four or five colors is printed from as many separate plates as there are colors; that is, one plate for each color. As these colors are printed, one after the other, the fine details of the picture must "register" exactly, otherwise the whole cover is just a colored blur.

At first, magazines were printed sheet by sheet on cylinder presses, and cost twenty-five to fifty cents apiece. If they could be reduced in price, many more readers could afford to buy them, and circulations would grow. Also, newspaper publishers were beginning to print magazine sections and colored supplements for their Sunday issues, and wanted presses for such work. This demand interested the third Robert Hoe, and several other American inventors. The Hoes built several rotary presses to do fine, fast work for *The Century Magazine* between 1886 and 1890. Walter Scott is credited with building the first press to print a colored newspaper supplement. The New York *World* used the first in the early nineties to print its famous "yellow kid" humorous section, the first "Sunday comic."

One of the most important inventions in this field was evolved by C. B. Cottrell, who did much to make five and ten cent magazines possible. To overcome smudging in printing both sides of a web of coated paper, he made his press print one side, and brought it against a surface of clean white muslin while the other side was being printed. This sheet of muslin was constantly renewed—the "shifting tympan" as it is called. After several failures, in 1892 he set up one of his presses to print *The Youth's Companion* in Boston. The publishers doubted the possibility of printing a fine magazine so rapidly. Cottrell and his helpers ran off the week's edition. Still doubtful, they would not accept and pay for the press until he and all his men had been shut out and the regular pressmen had printed the next week's issue themselves.

Cottrell was a business man when the Civil War ended, and with Nathan Babcock, a skilled mechanic, took over a bankrupt foundry in Westerly, Rhode Island. One day, Charles

Potter, Jr., who sold old presses, came in to see their plant, and suggested that they build presses. Together, they built a Cottrell-Babcock-Potter press, with improvements suggested by Cottrell, who had real inventive genius. After a while, Babcock and Potter each set up a press-building plant for himself. Out of these three separate establishments much of our modern magazine-making machinery has come. Besides his shifting tympan, Cottrell made other improvements. He died in 1893, seventy-two years old.

Magazine presses are now as wonderful as newspaper presses in their speed. In one great Philadelphia magazine plant, 120 giant presses run day and night, printing more than 12,000,000 magazines a month, each with 100 to 200 pages, with fine colored covers and illustrations, all bound and trimmed—twenty mail-cars full of magazines daily. It is such speed and quality of work that has made it possible to print magazines by the million and sell them at astonishingly low prices.

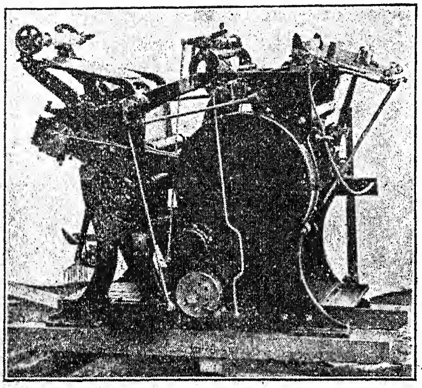
Inventors Attack the Last of the "Cheese-Squeezers"

There are also high-speed book presses which print, fold, and deliver all the sheets for a book of several hundred pages, ready for the bookbinder. The latest additions to the press family are the automatic machines for printing letter-heads, pamphlets, and circulars. It is predicted that soon, when these automatics are in wider use, the last printing-machine that can rightfully be called a "press" will disappear.

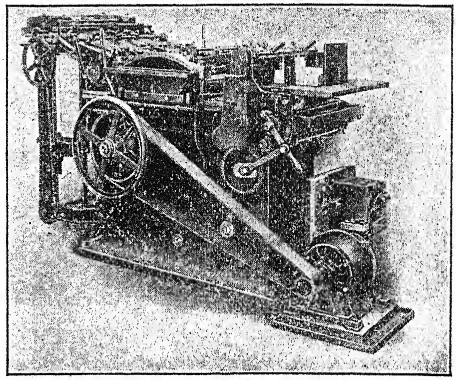
In hand-press days, "job"-work was printed on the same machine as newspapers and books. There was probably very little "job-work," because such printing costs are relatively expensive. When cylinder and rotary presses cheapened newspaper printing, inventors turned their attention to job-presses. Dozens of practical machines were invented for the job-printer, machines operated at first by hand-lever or foot-treadle, and later by power. These were truly presses, because they had a platen that pressed the paper against the type. To make it work faster than the hand-press, the platen was hinged to open and close like a jaw, and the type was automatically inked by

rollers, running down as the jaw opened, and up over an ink table as it closed.

Until about 1900, such presses were fed a sheet at a time by boys or girls paid a few dollars a week. But wages began to rise. Job-printers wanted presses that would feed themselves and also turn out the work faster. Inventors soon met the demand. At first, they devised machines that would automat-



Courtesy Paul Nathan.



Courtesy C. H. Hoppe.

(Left) A STANDARD HIGH-SPEED AUTOMATIC JOB-PRESS.
(Right) THE AUTOPRESS FOR FAST AUTOMATIC JOB-PRINTING.

ically feed a regular job-press, but it soon became clear that new principles were needed. A California printer named Hoag has been given credit for making the first truly automatic job printing-machine, the autopress, a distinctly new printing-machine, with which speeds of 5,000 impressions an hour are possible. The sheets are fed in and taken out automatically.

Another automatic job-press, the Standard, is the development of Henry A. Wise Wood. It has a platen, but is built so heavily that it has a speed of 3,500 impressions an hour. It is fed automatically by a suction device which takes the sheets from the under part of a pile, passes them through the press rapidly one by one, and drops them out at the bottom.

Still another automatic, the Kelly press, is interesting as a machine and also because it shows how wide a knowledge an inventor may need. Its inventor, W. M. Kelly, had been a compositor, pressman, type salesman, and an expert repairer of

typesetting-machines, and had sold printers' machinery and supplies in India, Australia, South Africa, and other parts of the world. In 1912, he invented a device for setting and distributing the typewriter type used in business offices to print circulars. A press was needed to go with it. He drew plans for such a press and was advised to make it for job-printers instead of office use. A small model was built, and a larger one with an automatic feed was finished in 1914. Since that time it has been changed in many ways. It is a small cylinder press with an automatic feed air being used to separate and feed the sheets of paper. It has a speed of 3,600 impressions an hour. The hand-feeder often missed an impression or spoiled a sheet. The Kelly press stops if a defective sheet turns up or two sheets stick together.

Our automatic job-presses were carried right up to the front in France during the war, on American motor-trucks, and used to print propaganda circulars which were dropped from airplanes behind the German lines almost as fast as the printers turned them out.

The last word in printing came from America, and was addressed to the countrymen of great-great-grandfather Gutenberg, who has come down in history as the first word!

CHAPTER II

WRITING BY MACHINE

ONE July day in 1867, an odd genius came into the Milwaukee telegraph office and asked the chief operator for a sheet of carbon-paper.

Now, carbon-paper was almost a curiosity then. About the only use that had been found for it was to make several copies quickly of newspaper despatches as telegraphers took them from the wire and wrote them down in longhand.

The chief operator knew this visitor. He was Christopher Latham Sholes, a man already famous in Milwaukee for the many things he had done. At various times he had been a printer, a newspaper-publisher, an editor, a member of the Wisconsin legislature, commissioner of public works, and postmaster of Milwaukee. Now he was the collector of customs in that city. He was an inventor, could tell a good story, make a good pun, quote poetry, play a game of chess. He was tall and slender, somewhat frail, with long flowing hair, and clear bright eyes that had a far-away look. Modest, gentle, kindly, a stranger would not have thought him a fighter. Yet he would turn like a lion to defend right against might, and all the more quickly if the right happened to be weak or getting the worst of it.

We want to know this man Sholes at the beginning of our story, because he was the father of the typewriter. And the telegraph operator, too, because he was present at the very beginning of the first real typewriter. His name was Charles E. Weller, a backwoods lad with little schooling, but an enormous reader. Working first in a printing-office, he had become a telegraph messenger, learned telegraphy and newspaper reporting, and was now studying shorthand, hoping to become a court reporter.

What did Sholes want with a sheet of carbon-paper? Young Weller was curious. He knew that Sholes had already invented a way to print the names and addresses of subscribers on the

margins of newspapers for mailing, also a machine that would number dollar bills or tickets from one upward, or print the page numbers in blank books.

"Come up to my office to-morrow about noon, Charlie," said Sholes, as he went out, "and I'll show you something that may be interesting."

Next day young Weller was on hand. The inventor still edited a newspaper up-stairs over the telegraph office. Charlie expected to see something new, and he did.

With some pieces of pine board, an old telegraph-key, a sheet of glass, and other odds and ends, Sholes had whittled out and assembled together a little piece of mechanism which he was showing to some gentlemen. Taking his borrowed sheet of carbon-paper and a thin sheet of white paper, he slipped them into his machine, against the piece of glass. Moving the paper slowly with one hand, he tapped the telegraph-key with the other. On the end of the telegraph-key was a letter "w" cut in brass. Sholes's little device was a "writing-machine." It wrote only the one letter over and over, like this:

wwwwwwwwwwwww

But he said that with thirty or forty such keys, each having a letter or figure, he could make a machine that would write anything.

He had it clearly pictured in his mind and gave a lot of technical details which Weller, who did not know much about mechanics, found it hard to understand. All out of such a patched-up arrangement that wrote "wwwwwww"! But years later the little machine seemed so important that Weller built a model of it as nearly as he could. The original had disappeared.

Typewriter Inventors Began by Wanting to Help the Blind

Sholes was not the first inventor to conceive the idea of a machine that would write. As far back as the year 1714, an English water-works engineer named Henry Mill took out a patent for a machine which was said to "impress letters on paper as in writing." Nothing more is known about it, however: nor about an "embossing machine" invented in France

in 1784; nor of the first American attempt at a writing-machine, called a "typographer," patented by a Mr. Burt, all records of which were destroyed in a great fire in Washington in 1836.

A Frenchman named Progin patented a "typographic machine or pen," in which type-bars were used, a principle still found in the typewriter as we know it to-day. An American named Charles Thurber built a typewriter capable of actual work in 1843. It wrote very slowly, but Thurber added other useful principles—the carriage that holds the paper and slides along as a line is written, and the way of turning the paper when a line is done.

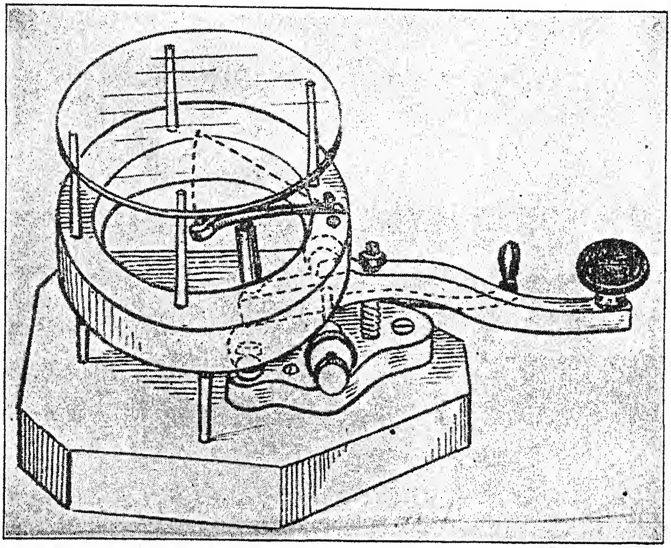
Several early inventors tried to build a typewriter that would raise letters on the paper, to be read by the blind. One of them, a Frenchman, Pierre Foucald, received a gold medal for such a machine in 1850—he was blind himself. Sympathy with the blind was the idea with which nearly every typewriter inventor started. Blind people were cut off from ordinary reading and writing, yet needed them so much! This sympathy started another American inventor, Alfred E. Beach, an odd genius too. He is remembered now as editor of *The Scientific American*. Beach wanted to help the blind, too. Between 1847 and 1856, he built several writing-machines. They were mostly made of wood, as big as a bushel basket, but incorporated principles that are still used. Beach's firm took out hundreds of patents for inventors, and that made a great lot of writing. Before Beach got very far, he saw that the real place for his writing-machine was in business offices, doing just such work as copying patent papers.

By this time there was keen rivalry between English and American writing-machine inventors—a race to see which country would build the first real typewriter. Technical editors on both sides of the ocean began to write about different machines and the ideas which inventors were working out. It is easy to imagine how warm the discussion grew when a promising typewriter was invented in London in 1866—but by an American living there, John Pratt.

Pratt's machine had the whole alphabet on one plate. When its "A" key was pressed, that letter swung in place, a hammer hit it through the paper, and wrote the letter. It was

the best device up to that time, and everybody talked about it. Some said the time would come—and soon, when a reporter with a writing-machine would take down speeches as fast as they were spoken. Why not, with the railroad, steamboat, sewing-machine, electric telegraph, revolving printing-press, and like wonders on every hand?

These arguments flew so thick and fast that in July, 1867,



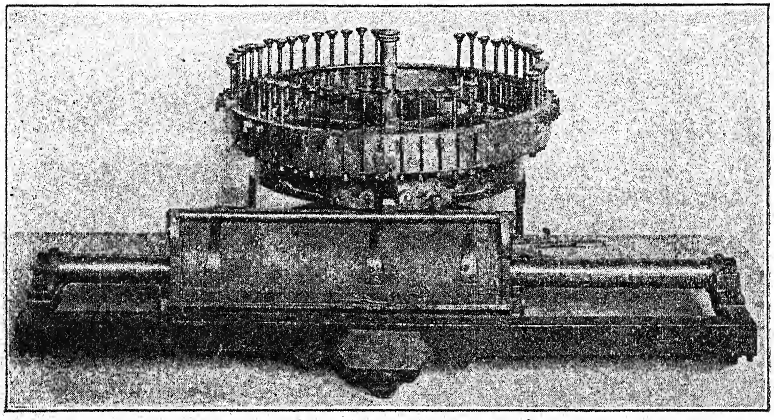
SHOLES'S FIRST, RUDE, ONE-LETTER TYPEWRITER.
Drawn from memory by Charles Weller.

Alfred Beach wrote an article for his *Scientific American*, showing the great value of a practical typewriter, and foretold what it would do. He spoke as a typewriter inventor himself. So many records and legal papers and letters had to be written and copied as the world's business grew that pen-and-ink copyists could not keep pace with the work much longer. A successful typewriter meant a revolution almost as great as that caused by the invention of printing in the world of books. Beach's enthusiasm led him to predict that the schoolboy of the future would be taught to write only his name with a pen—everything else would be written by "playing on the literary piano." That part of it did not come true, we know, but everything else did.

When the real typewriter was finally born, it had several uncles as well as a father. One of them was Carlos S. Glidden, whom Sholes had told about his device for printing numbers. It made such a deep impression on Glidden that he helped to work it out. That gave Glidden another idea.

"If you can write numbers, why not letters?" he reasoned.

Sholes did not seem to see the point, so Glidden showed



THURBER'S TYPEWRITER OF 1843.

him the article about the typewriter in *The Scientific American*. Sholes read it over and admitted that the idea was practical. But not Pratt's machine.

"It is too complicated," he objected, "and badly made. I know that I can build something better."

"Why not let us do it together?" suggested Glidden, and Sholes agreed. They took in a third person, Samuel W. Soule, who was something of an inventor too, but more useful as a practical machinist. He could build a thing quickly after Sholes made the idea clear, and often improve it. In fact, he suggested something found to-day in nearly every typewriter—the principle of having all the type strike in the same spot, the principle of "converging type-bars."

Glidden and Soule were the men to whom Sholes was showing his first one-letter model when Charlie Weller saw it. This model was built only a week after Sholes read Alfred E. Beach's

NORWICH 3. FEBRUARY 1846

GENT.

, WE HAVE, AT LENGTH COMPLETED ONE OF THURBERS MECHANICAL CHIROGRAPHERS. ALTHOUGH YOU WILL NOTICE IMPERFECTIONS IN THE FORMATION OF THE LETTERS IN THIS COMMUNICATION, YET THERE IS NOT A SINGLE DEFECT WHICH DOES NOT ADMIT OF AN EASY AND PERFECT REMEDY. I AM PERFECTLY ~~SATISFIED WITH IT BECAUSE I DID NOT LOOK FOR I~~ PERFECTION IN THIS FIRST MACHINE. THE DIFFICULTY IN THIS MACHINE IS THAT THE CAMS ARE NOT LARGE ENOUGH. THIS, OF COURSE, CAN BE AVOIDED. I THINK MR. KELLAR TOLD WHEN I LAST SAW HIM THAT IF I WOULD WRITE TO HIM INFORMING HIM WHEN I SHOULD BE IN WASHINGTON HE MIGHT BE ABLE TO MAKE SOME SUGGESTIONS ABOUT A HOME DURING ~~MY~~ STAY IN WASHINGTON. I SHALL WISH TO EXHIBIT THE MACHINE, TO SUCH GENTLEMEN AS MIGHT ~~TAKE INTEREST~~ IN A THING OF THIS KIND. I DO NOT WISH TO ~~MAKE~~ A PUBLIC SHOW OF MYSELF OR MY MACHINE. I WANT ~~TO SHOW~~ IT ~~TO MEN~~ WHO CAN APPRECIATE AND UNDERSTAND MACHINERY. MR. ROCKWELL, OUR REPRESENTATIVE IN CONGRESS VOLUNTEERED TO GET ~~ME~~ A ROOM & I HAVE WRITTEN TO ~~HIM~~ ON THE SUBJECT. STILL I THOUGHT IN CONSEQUENCE OF YOUR MORE THOROUGH ACQUAINTANCE IN THE CITY THAT YOU MIGHT BE ABLE TO MAKE SOME SUGGESTIONS WHICH MIGHT BE BENEFICIAL TO ME IN EXHIBITING HE MACHINE. I WANT A ROOM LARGE ENOUGH TO RECEIVE SUCH COMPANY AS MAY WISH TO SEE THE MACHINE. I WANT A ROOM WHERE I CAN SAFELY LEAVE IT WHEN I AM ABSENT AND WHERE NO ONE WOULD BE LIABLE TO GO IN AND INJURE IT. EXCUSE THE LIBERTY I HAVE TAKEN, AND BELEVE ME

YOURS, TRULY. CHARLES THURBER.

MESSRS. K~~ELLER & GREENOUGH~~

PATENT ATTORNIES.

WASHINGTON. D. C.

Courtesy Underwood Typewriter Company.

SPECIMEN OF MACHINE-WRITING FROM THURBER'S "CHIROGRAPHIE," 1845.

article. The inventor had studied previous typewriters to learn their good points and avoid bad ones. He had so clear an idea of what he wanted to do that the three partners started right in to build the first typewriter in a little Milwaukee machine-shop known as "Kleinsteuber's."

A Customer for the First Real Typewriter Before It Is Built

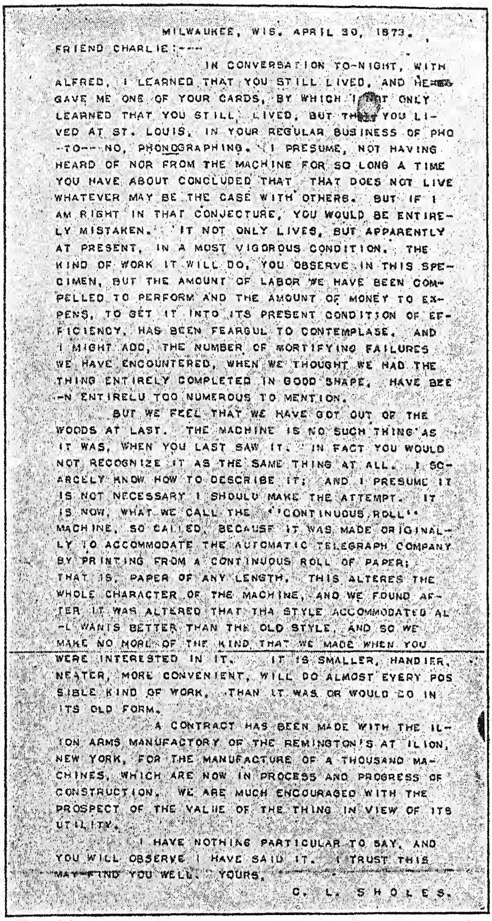
Charlie Weller was right on their heels. He knew court reporters had to write hundreds of pages of records by hand. This was drudgery, and it made reports of trials so costly that few people who went to law could afford them. A machine which would write legal papers quickly and cheaply seemed about the biggest thing he had ever heard of. If he became a court reporter, he wanted one, and he wanted one so badly that Sholes promised him the first machine that left the shop, to be tried in actual court reporting. The work of building that first machine progressed slowly, because every part was strange to Kleinsteuber's machinists. But Charlie Weller walked a couple of miles every day to see how the machine was coming along and watched its growth with breathless interest.

That was the only name they had for it then—just "the machine." What should it be called? "Printing-machine," said one, but the machine did not really print like a press. "Writing-machine," said another, but that did not seem to fit either; for it did not really write. Finally, Sholes himself invented a name—the "typewriter." A strange-sounding word then, but it came nearest to telling what the machine really did, and is now the common name wherever English is spoken, although in some other languages "writing-machine" is used instead.

The first "typewriter" was finished three or four months later, in the autumn of 1867. It did not look much like the compact typewriters of to-day, yet there was the movable carriage, and the lever for turning the paper from line to line, and the converging type-bars, and even the keyboard. Indeed it was more like our typewriters than any writing-machine that had been invented before.

The keyboard was like that of a piano. The keys were of

black-walnut wood, in two rows, with the letters and figures painted in white. The letters of the alphabet read from A to Z, the first half on the lower row of white keys, and the other half on the upper row of black keys. This machine printed



MILWAUKEE, WIS. APRIL 30, 1873.

FRIEND CHARLIE:---

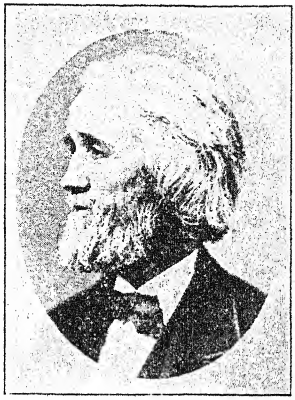
IN CONVERSATION TO-NIGHT, WITH ALFRED, I LEARNED THAT YOU STILL LIVED, AND HE GAVE ME ONE OF YOUR CARDS, BY WHICH I NOT ONLY LEARNED THAT YOU STILL LIVED, BUT THAT YOU LI-VED AT ST. LOUIS, IN YOUR REGULAR BUSINESS OF PHO-TO--NO, PHONOGRAPHING. I PRESUME, NOT HAVING HEARD OF NOR FROM THE MACHINE FOR SO LONG A TIME YOU HAVE ABOUT CONCLUDED THAT THAT DOES NOT LIVE WHATEVER MAY BE THE CASE WITH OTHERS. BUT IF I AM RIGHT IN THAT CONJECTURE, YOU WOULD BE ENTIRE-LY MISTAKEN. IT NOT ONLY LIVES, BUT APPARENTLY AT PRESENT, IN A MOST VIGOROUS CONDITION. THE KIND OF WORK IT WILL DO, YOU OBSERVE IN THIS SPE-CIMEN, BUT THE AMOUNT OF LABOR WE HAVE BEEN COM-PELLED TO PERFORM AND THE AMOUNT OF MONEY TO EX-PENS, TO GET IT INTO ITS PRESENT CONDITION OF EF-FICIENCY, HAS BEEN FEARGUL TO CONTEMPLASE. AND I MIGHT ADD, THE NUMBER OF MORTIFYING FAILURES WE HAVE ENCOUNTERED, WHEN WE THOUGHT WE HAD THE THING ENTIRELY COMPLETED IN GOOD SHAPE, HAVE BEE-N ENTIRELU TOO NUMEROUS TO MENTION.

BUT WE FEEL THAT WE HAVE GOT OUT OF THE WOODS AT LAST. THE MACHINE IS NO SUCH THING AS IT WAS, WHEN YOU LAST SAW IT. IN FACT YOU WOULD NOT RECOGNIZE IT AS THE SAME THING AT ALL. I SC-ARCELY KNOW HOW TO DESCRIBE IT; AND I PRESUME IT IS NOT NECESSARY I SHOULU MAKE THE ATTEMPT. IT IS NOW, WHAT WE CALL THE ''CONTINUOUS ROLL'' MACHINE, SO CALLED, BECAUSE IT WAS MADE ORIGINAL-LY TO ACCOMMODATE THE AUTOMATIC TELEGRAPH COMPANY BY PRINTING FROM A CONTINUOUS ROLL OF PAPER; THAT IS, PAPER OF ANY LENGTH. THIS ALTERES THE WHOLE CHARACTER OF THE MACHINE, AND WE FOUND AF-TER IT WAS ALTERED THAT THA STYLE ACCOMMODATED AL-L WANTS BETTER THAN THE OLD STYLE, AND SO WE MAKE NO MORE OF THE KIND THAT WE MADE WHEN YOU WERE INTERESTED IN IT. IT IS SMALLER, HANDIER, NEATER, MORE CONVENIENT, WILL DO ALMOST EVERY POS SIBLE KIND OF WORK, THAN IT WAS OR WOULD DO IN ITS OLD FORM.

A CONTRACT HAS BEEN MADE WITH THE IL-ION ARMS MANUFACTORY OF THE REMINGTON'S AT ILION, NEW YORK, FOR THE MANUFACTURE OF A THOUSAND MA-CHINES, WHICH ARE NOW IN PROCESS AND PROGRESS OF CONSTRUCTION. WE ARE MUCH ENCOURAGED WITH THE PROSPECT OF THE VALUE OF THE THING IN VIEW OF ITS UTILITY.

I HAVE NOTHING PARTICULAR TO SAY, AND YOU WILL OBSERVE I HAVE SAID IT. I TRUST THIS MAY FIND YOU WELL. YOURS,

C. L. SHOLES.



Courtesy Underwood Typewriter Co.

(Right) CHRISTOPHER LATHAM SHOLES, FATHER OF THE TYPEWRITER.

(Left) SHOLES RECORDS HIS PROGRESS.

A typewritten letter from Sholes to Charles Weller, referring to the contract made with the Remingtons to build better typewriters.

The first typewriter wrote only capital letters. They could not stand the wear and tear of every-day use. It was through the efforts of the skilled mechanics of the Remingtons that the typewriter was eventually brought to commercial perfection.

only capital letters, but it had figures from 2 to 9. The letter "I" was used for the figure "1," and the letter "O" for zero. There was also a comma, period, semicolon, hyphen, question-mark, dollar-sign, and diagonal stroke.

Sholes and Soule soon saw that something was wrong with this keyboard. They were both printers. Letters in a printer's case were arranged so that those most often used are near-

est at hand instead of the way they follow one another in the alphabet. A printer would soon think of such a keyboard arrangement for a typewriter. Sholes and Soule worked out a four-bank keyboard, arranged as nearly like the printer's case as possible. But they could not follow it exactly, because some of the keys clashed with others. By changing these keys to new positions they finally worked out a keyboard much like that of the modern typewriter.

Something else has lasted all these years. Step into any typewriter showroom to-day. The salesman will sit down at a typewriter and rattle off a sentence to show how well it works. That sentence is nearly always the same, and this is the reason. When Sholes's first machine was ready to write, an exciting political campaign was in progress in Milwaukee. Almost the first sentence written was, "Now is the time for all good men to come to the aid of the party," and it is still used to show how typewriters work.

When Typewriters Wrote Only Capital Letters—and Stuttered

Charlie Weller got the first machine in January, 1868. By that time he had become a shorthand reporter in St. Louis, where the machine was sent. Lawyers were suspicious of shorthand. What did the stenographer write with his mysterious pothooks? They could not read them! So lawyers took scraps of testimony in longhand, and depended upon these and their memories for the record of a trial. Disputes as to what a witness had said were settled by the judge, who relied on his memory.

Charlie Weller joined the only firm in St. Louis that did shorthand reporting in the courts. There was not enough legal work to keep him and his partners busy. So they took down lectures, sermons, and political speeches in shorthand for the newspapers. Some months before there had been a long impeachment trial, and one of Weller's partners had reported it in shorthand. He had never written out his notes, however. Soon after Weller received his strange typewriting-machine, the report of this trial was needed. He wrote it out on the machine. This first typewriter wrote only capital letters, remem-

ber, and it wrote these out of line. The letters often "stuttered" or stuck. The lines were unequally spaced. A typewriter ribbon could not be bought; a roll of silk ribbon was bought at a dry-goods store, soaked several hours in writing-ink, hung up overnight to dry, and placed in the machine. But this first typewritten report of a trial in court answered all purposes, because it was used as "copy" for the printer.

The first typewriter was followed by others. In their little Milwaukee machine-shop Sholes, Glidden, and Soule began five years of change, experiment, and improvement. After a better keyboard had been worked out, they changed the wooden keys to metal rods and set their type-bars in steel bearings. The paper had rested in a flat frame against which the type struck in writing. For this they substituted a rubber roller. Machine after machine was built, and each seemed so great an improvement on the last that, more than once, Sholes thought they had reached perfection.

"The machine is done, and I want some more worlds to conquer," he wrote Weller. "Life will be most flat, stale, and unprofitable without something to invent." But there was plenty of invention still ahead of him, as we shall see. The typewriter had a father, and two uncles, and Charlie Weller was a sort of nephew. Now it needed a godfather, and one turned up in the oddest way.

James Densmore Buys an Interest in Sholes's Invention

When Sholes's first machine would actually work, he wrote dozens of letters upon it, sending them to friends and public men. You can imagine what a curiosity a typewritten letter was then. One of these letters fell into the hands of Mr. James Densmore, a business man living in Meadville, Pennsylvania. He was so impressed that he wrote Sholes right away, asking if he could become a partner. Sholes talked it over with Glidden and Soule, and told Densmore he could have a quarter interest in the business if he would pay all past expenses. Densmore accepted without even knowing how much the expenses would be, sent the money when it was asked for, and thus bought an interest in an invention he had never seen. He had un-

bounded faith in the future of the typewriter, and this faith was now going to help Sholes through a very trying period.

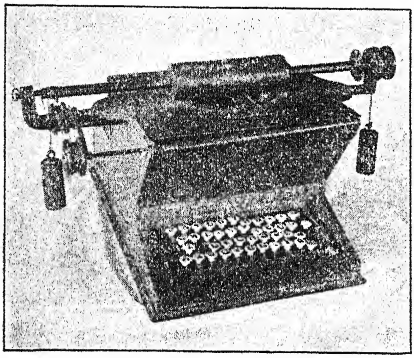
Several months went by before Densmore met Sholes and saw the typewriter. Then he said it was "good for nothing except to show that the idea is feasible." He had plenty of faith in the idea, but pointed out defects in the machine and urged that they be remedied. Soule dropped out, leaving Sholes, Densmore, and Glidden to go on. Machine after machine was built and sent out to be tried by shorthand reporters. The machines broke down after steady use. Twenty-five or thirty such machines were made, each a little different and a little better. They wrote well enough for a week or two. Then something would break or wear out. One reporter in Washington, James O. Clephane, ruined machine after machine and found fault after fault, until even the gentle Sholes lost his temper, saying: "I am through with Clephane!" But Densmore said: "This candid faultfinding is just what we need. Where Clephane points out a weak lever or rod, let us make it strong. Where a spacer or an inker works stiffly, let us make it work smoothly. Then, depend upon Clephane for all the praise we deserve." Years later Clephane helped Ottmar Mergenthaler, the inventor of the linotype.

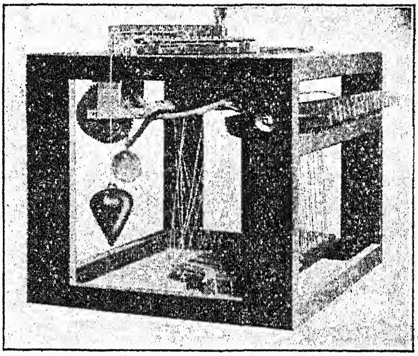
Sholes was a man with many fine traits of character. His broad, open mind became interested in a dozen different things, and his great heart made him countless friends. He was so unselfish that he seldom thought of money, and in fact said he did not like to make it because it was too much bother. For this reason he paid little attention to business matters. He made very little money out of his typewriter in the end, but was not at all sorry, being quite as well satisfied to see his invention spread all over the world and to be called "the father of the typewriter." He lacked the patience to plod at humdrum work, and hard, persistent work was what the typewriter needed. Without Densmore, he might never have kept at the task.

"Just what we want!" said Densmore, the business man. "Unless we can build machines that stand up, typewriters that anybody can use, we might as well stop right here." He would cheer Sholes up and set him working again. For more

than five years Densmore furnished money and encouragement. They built fifty machines at a cost of $250 each between the fall of 1867 and the spring of 1873. The typewriter grew better, but they had not been able to build and sell it by dozens and hundreds.

Then they found out what was wrong. Neither Sholes nor Densmore were machinists, much less mechanical engineers. And the machinists they hired to do their work had never made





(Left) THE MACHINE THAT SHOLES BROUGHT TO ILION IN 1876.

The case is opened to show the keyboard. Note that the letters are arranged nearly as they are in the standard keyboard of to-day.

(Right) PATENT OFFICE MODEL OF THE MACHINE PATENTED JULY 14, 1886, BY SHOLES, GLIDDEN, AND SOULE.

parts fine enough for such a machine. Nor could they pass expert judgment upon the mechanical principles of such a machine.

Who would have thought of turning the job over to gunsmiths? Yet that is just what was done. As they seemed to be making little headway, Sholes and Densmore took their typewriter to one of the best mechanical experts in Milwaukee, Mr. G. W. N. Yost, who afterward became a typewriter inventor and builder himself.

"What do you think of it?" they asked. "What can be done to make it stand up in steady, every-day work?"

Yost suggested various changes and said the typewriter must be built with the accuracy and skill needed in firearms. He sent them to the Remingtons, at Ilion, New York. Sholes and Dens-

more brought their typewriter to Ilion, in 1872, and received the help of as fine a group of mechanical experts as could have been found anywhere in the country at that time. Sholes had spent all his money and even mortgaged his home. Densmore was still full of faith in the machine, and in his partner, but knew that something was wrong.

Up to this point, the typewriter had been the work of amateurs. Now it ceased to be an experiment. The Remington experts gathered round the machine, took it apart, talked it over, found out what was wrong, and made improvements. They had fine machinery and skilled machinists to carry out their plans. In a few months they were building typewriters that could be sold to any one. They would work, and not break down, and could be built by dozens, hundreds—thousands, if people wanted that many. The Remingtons were so pleased with the machine that they bought it from Sholes and Densmore. It is said that Sholes was satisfied with cash, and so got only $12,000. Densmore was a shrewder business man, and took a royalty, which in after-years paid him many times $12,000 annually. But Sholes never complained.

"All my life I have been trying to escape being a millionaire," he said humorously, "and now I think I have succeeded."

Going back to Milwaukee, he went right on making typewriter experiments, helped by two sons. They invented a new typewriter which was simpler, had fewer parts, was less likely to get out of order, and was also "visible"—that is, the operator could see what he was writing as he struck the keys. This afterward became a very important principle in typewriters, and it is interesting to note that Sholes had it in mind from the beginning, for his first machine that wrote only the letter "w" had a glass top through which one could watch it write.

Sholes had never been a strong man. His health began to fail under constant work at the desk and in the shop. He became consumptive, and the last nine years of his useful life were spent in search of health. Even when he was not strong enough to sit up, his bed became his workshop. He died in the early nineties, leaving six sons and four daughters.

Nearly every one who came in contact with Sholes while he was working on his typewriter caught his enthusiasm. A

friend named Craig, who saw that all business letters would some day be written on typewriters, brought Sholes to Thomas A. Edison's laboratory in the early seventies, before he went to

Courtesy Underwood Typewriter Company.

THE FIRST TYPIST—ONE OF SHOLES'S DAUGHTERS.

The early typewriters of Sholes were made to be locked up when not in use.

Ilion. Edison examined his wooden model of a writing-machine and took time to help him improve it mechanically. But Edison was an inventor, too—not expert in the building of fine machines by the thousand. He thought it would be a hard thing to make commercially. "The alignment of the letters was awful," he has said since. "One letter would be a sixteenth

of an inch above the others, and all the letters wanted to wander out of line." Edison worked on it until the machine gave fair results, and found an early use for typewriters in automatic telegraphy.

Yost caught Sholes's enthusiasm, and invented the first machine that wrote small letters as well as capitals, the caligraph, which was ready about 1878. Densmore became a typewriter manufacturer, making a machine bearing his name. Franz X. Wagner was working with the Remingtons when Sholes came to Ilion, and helped develop his machine. Then he worked with Yost, and after that turned typewriter inventor himself, making the first front-stroke visible writing-machine sold to the public. That was patented in 1894, and became known as the "Underwood." Charlie Weller did not turn inventor, but his belief in Sholes and the typewriter helped to make it known to the public.

Sholes always believed that his greatest invention would help women earn a living. He wanted to perfect the typewriter, not to make money, but to abolish drudgery.

"Father Sholes, what a wonderful thing you have done for the world!" said a daughter-in-law shortly before he died.

"I don't know about the world," was the reply, "but I feel that I have done something for the women who have always had to work so hard. This will help them earn a living more easily."

How the Typewriter Made Office Jobs for Women

Before the typewriter was invented, few women were employed in business offices. If a refined, educated woman had to earn her living then, or a girl wanted to earn money, there were only teaching school, clerking in a dry-goods store, or a place as governess or librarian—that was about all. Older women kept boarders or lodgers. To-day, thousands of women work in offices at tasks which were unknown before the typewriter and other office machines appeared. The typewriter has rightly been called the "great-grandfather of office machinery." Because it is so common, we lose sight of its wonders. What would a telephone or electric light company have to charge for service if its thousands of bills were written out in longhand

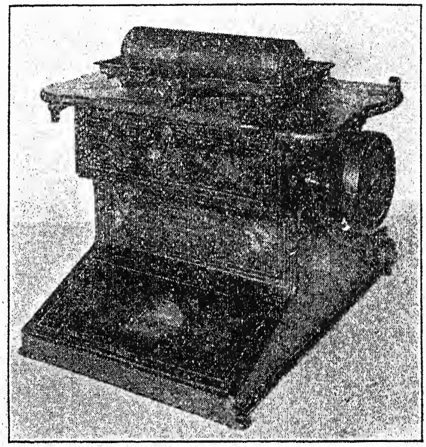
every month, its letters written with pen and ink, its records kept by old-fashioned bookkeeping methods? The office work might cost as much as the telephone service or electric current! Gas and electricity would be luxuries that only well-to-do people could afford. If all office machinery, including the typewriter, were suddenly taken away from business men, they could find some way to get along without them, of course. But they could afford so few records that one of the greatest elements of business efficiency and progress would be lost. For it is upon the cheapness and abundance of machine-made information and communication that modern business grows. With his daily reports from every department, his tables and figures, the business man to-day guides his enterprise much as a ship is steered through unknown waters by compass, chart, and soundings. The mechanical method of gathering such information is one of the striking things of our age—and it is all machine-made information, largely the product of girls and women who learn simple tasks. The young lady who will take the trouble to learn just typewriting—not stenography—by a few weeks' practice can now earn more as a copyist than her mother would have been paid for teaching school a generation ago.

The First Remington Typewriter

When the Remingtons bought Sholes's typewriter, it was agreed that they could put their own name upon it. Thus the first typewriter actually sold to the public bore the name "Remington." It took more than five years to invent and build this machine. Now eight years more were to be spent teaching people to use it.

"Of the first Remington typewriters placed on the market in 1874, only about 400 were sold," says Mr. C. V. Oden, a veteran writing-machine man who has made the history of the typewriter his hobby. "Many of the machines were returned, some defective. But the real trouble was, that business men did not yet realize how much of their work the typewriter could do. The first efforts to sell machines were unsuccessful. Sales rights were first given to an electrical company, and then a scales company. A legal sham battle between typewriter inventors was arranged in the belief that people would be inter-

ested—but they were not. In 1882, a couple of years before I entered the business as a boy, the firm of Wyckoff, Seamans and Benedict was formed to sell typewriters. W. O. Wyckoff was a court reporter at Ithaca, New York. C. W. Seamans had been typewriter sales manager for one of the previous selling companies. H. H. Benedict was a Remington-Arms man. The education of the public began—a hard job. If you bought



(Left) MADE FOR THE EXPOSITION IN 1876.

This mother-of-pearl ornamental Remington, one of the first typewriters made at Ilion, was shown at the Centennial Exposition of 1876, and hardly noticed by the public.

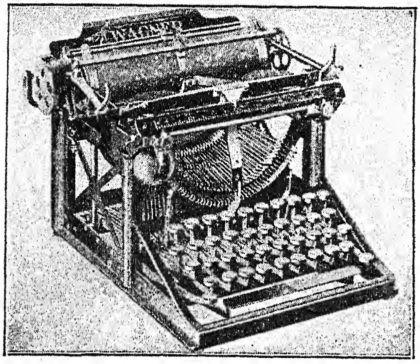
(Right) MARK TWAIN'S TYPEWRITER.

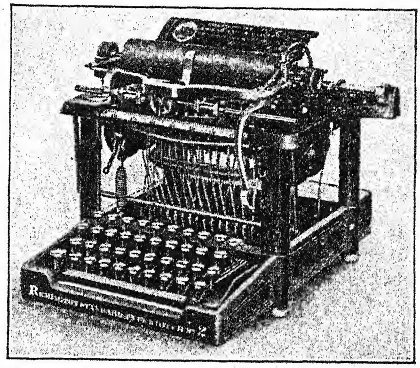
This is believed to be Mark Twain's famous typewriter upon which he copied "Tom Sawyer" for the printer—the first typewritten book manuscript.

a typewriter and used it for letters, people to whom you wrote jumped to the conclusion that you thought they could not read pen-writing! The machine was also looked upon as a luxury or affectation. Mark Twain bought one of the first, in 1875, and copied *Tom Sawyer* upon it, probably the first typewritten book manuscript ever sent to the printer. But he asked us not to let people know that he owned one of these machines, saying that whenever he sent a typewritten letter to anybody he was always asked to tell what the typewriter was like, and how he was making out with it. 'Oliver Optic,' the beloved boys' writer of that day, was more encouraging—he said he

could write about two-thirds as fast on the typewriter as with a pen, that it was less drudgery, and that he hoped to do better with more practice."

After the Remingtons had spent great sums, things took a turn for the better about 1882. The new sales firm was enterprising. People began to buy and use typewriters. Each sale made new customers. Soon the business grew so that better





(Left) THE WAGNER TYPEWRITER OF 1894.
From this machine the Underwood was developed.
(Right) THE FIRST SHIFT-KEY REMINGTON TYPEWRITER (1878).
The machine wrote small as well as capital letters.

machines could be built. In 1886, the typewriter was separated from other Remington enterprises and became a business in itself.

The Inventon of the "Visible" Typewriter

The first machine wrote only capital letters. People wanted to write small letters, too—"lower case" as printers say. Capitals are harder to read. This demand was met by the "double-keyboard" machine, which had a separate key for each letter and character, seventy-eight altogether, nearly twice as many as the single-shift typewriter of to-day. Soon all typewriters wrote both large and small letters—people would not have any other kind. To obviate the striking of a separate key for each letter, the shift-keyboard was invented. In other words, each type-bar had two letters. The machine wrote small letters ordinarily, and if a capital was to be written the shift-key was

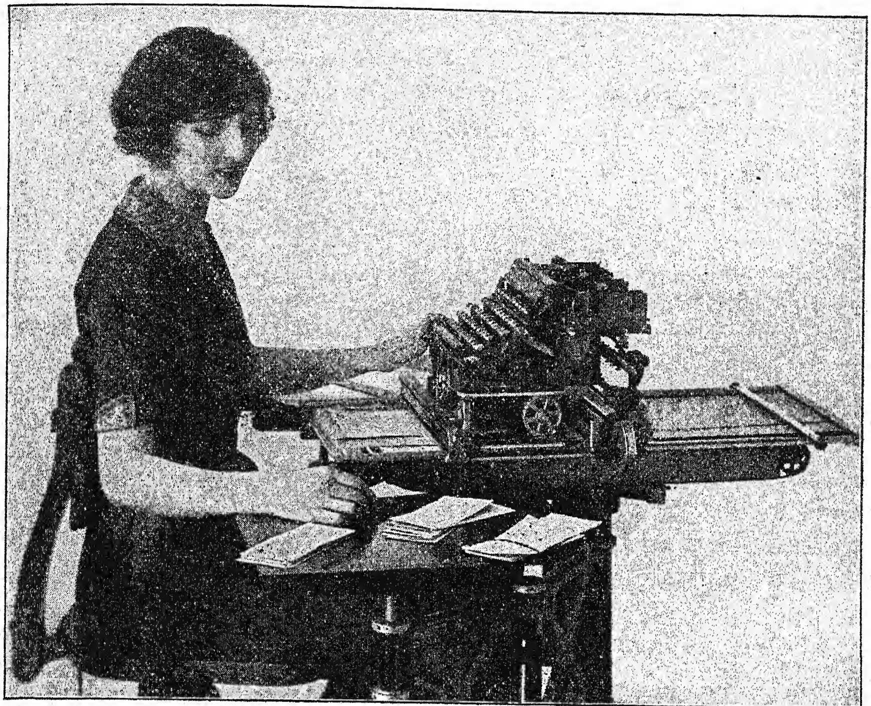
pressed. There were single and double shift machines—and are still. The double-shift machine has three characters on each type-bar, so that with only twenty-eight keys it is possible to have more characters than were possible with "double-keyboard" machines like the caligraph.

Then the first typewriters were "blind." That is, the typist could not see the line he was writing, but had to raise the roller or the carriage, which was hinged. This caused delay. Franz X. Wagner went about a good deal among typists, and knew that speed meant their bread and butter. So he invented the first practical "visible" machine widely sold to the public. We have seen that Christopher Sholes had realized the advantage of visible writing. But Sholes's visible machine was ahead of its time. People had been using typewriters ten years or more when Wagner's invention was patented and the public ready for it. Mr. John T. Underwood, who had been in the typewriter supply business, saw that this new machine met a real need. He bought the invention, gave it his own name, and built a few machines by hand in a little three-room plant in New York during 1894–5. Five years later he was building tens of thousands. Manufacturers of "blind" typewriters became alarmed. Clearly, the public wanted visibility. But to change blind machines, it was necessary to install new and expensive machinery in the factories. Not until 1908 was the last of the old blind machines transformed.

Then people wanted machines that could be carried about. The reporter, author, clergyman, private secretary, and travelling man needed typewriters far from office or home. One company tried to meet this need by placing typewriters in hotels, to rent at so much a day. But a typewriter that could be carried about as easily as a satchel was the real solution. One of the first typewriters light enough to be thus carried was the Blickensderfer, which fitted in a hand case. It was also one of the first typewriters sold at a moderate price. To-day, we have folding typewriters weighing only six or eight pounds, skeleton copies of standard machines, costing about half as much.

Still the public, like Oliver Twist, wanted more. And one of the things it wanted frightened printers. The first inventors

thought the typewriter would take the place of a pen—write letters and copy documents faster. But people quickly saw that, by using carbon-sheets, they could write several copies of a letter or document. By using thin paper more carbon copies could be made, but not as many copies as were often wanted.



Courtesy Elliott-Fisher Company.

MODERN ELLIOTT-FISHER BOOK TYPEWRITER.

Then Edison invented the mimeograph, by which the typewriter wrote a stencil on waxed paper, and from that thousands of copies could be made. No wonder the printers were alarmed! If a girl with a typewriter could make thousands of circulars, who would want printed circulars? But soon they saw that, for every job of printing lost in this way, the typewriter brought them several others.

People have wanted machines which would write more than one language, and inventors have provided "type-plate" machines with all the letters on one plate or wheel, which can be

taken off and another slipped on. To change from English to Spanish, or from a small type suitable for letters to a very large type needed in a sermon that is to be read, takes but a minute.

The Book Typewriter that Adds and Subtracts

Business men wanted typewriters that would keep books as well as write letters—set down columns of figures, add them up, give the totals, subtract, and so forth. Inventors busied themselves with the book typewriter. At first, bound books were replaced with loose-leaf records which would fit a typewriter, and "marginal stops" made it easy to write figures in columns. Then little adding and subtracting machines were attached to typewriters, so that a girl in making out a customer's bill, for instance, typed all the different items, and added them as fast as she wrote them. If there were amounts to be deducted, such as discounts, the machine would also subtract these.

Modern bookkeeping machines began to appear—super-typewriters. They not only write in the pages of great business record books opened flat, but put down many rows of complex figures, adding and subtracting, giving names, dates, and other items in one or more colors, making duplicates. Indeed, it is too bad that Alfred Beach could not have lived to see this "literary piano" with which, by playing on the keys, a girl can do, in five minutes, more work than an old-fashioned bookkeeper could do in an hour. If the bookkeeper made a slight mistake, it took him sometimes another hour to find it; but if the girl makes a mistake, the bookkeeping machine stops and points it out.

When the typewriter was young, people took offense at a typewritten letter. Now they take offense if it is not typewritten! That is, a mimeograph letter sent to a thousand people will not be read with nearly as much interest as a thousand letters separately typewritten. We all like to feel that we alone have received the letter addressed to us. Hence the automatic typewriter was invented. Another chapter of this book tells what inventors have done by punching holes in paper—a basic principle of great value. With the automatic typewriter, the letter is written that is to be sent to a thousand people—or a million, if you please. A roll of perforated paper that looks as though it might be played in a mechanical piano fits into a machine which operates an ordinary typewriter.

You write "Mr. David Crockett, Boonville, Ky.; My dear Mr. Crockett—" on the keys of this typewriter, turn a switch, a motor starts, and the roll of perforated paper writes the letter

Courtesy Cooper Engraving and Manufacturing Company.

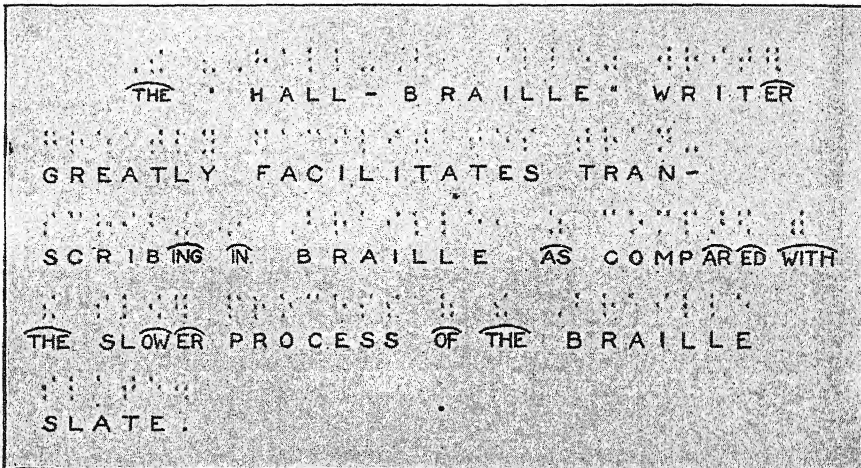
THE HALL-BRAILLE TYPEWRITER FOR THE BLIND.

This machine writes Braille, and is to the blind what an ordinary typewriter is to those who can see. A complete character or letter is made with one stroke of a key. As in the ordinary typewriter paper is used, but is fed from a roll, and is not used in single sheets. The carriage is equipped with a release, which permits movement of the platen to any position without using the spacer.

that has been punched in it, each character one by one, just as though the keys were struck by human fingers.

Because the typewriter and shorthand go together, inventors long ago began thinking about machines to write shorthand notes, doing away with the pencil. There are several such machines in use. They write on a narrow paper ribbon, have only

about a dozen keys, and with them the trained operator can take down words as fast as they are spoken. Some of them abbreviate the words, and others write a word at a stroke, because several characters can be struck and printed at once. Such machine-made notes have to be rewritten on a regular typewriter, of course. There are also several typewriters for



Courtesy Cooper Engraving and Manufacturing Company.

SPECIMEN OF WRITING ON THE HALL-BRAILLE MACHINE, AND TRANSLATION.

blind people—typewriters that punch raised dots in the peculiar alphabet used in books for the blind, and their writing is read by touching it with the fingers.

The typewriter played its part in the great war, showing that the world cannot get along without it. An American invention, it is made almost entirely in the United States. Only the Germans ever seriously tried to build typewriters, and with little success. Ship space was needed during the World War for munitions and food, so the Allies stopped buying typewriters, thinking they were not needed. But when the great armies went into the field, it took an enormous mass of writing to direct them—orders, despatches, letters, reports, records. Writing-machines were taken from offices and sent to the front, and soon there was a typewriter famine. When we entered the war, the government took three out of every four new typewriters made.

Experts figure that in 1919 the world made 875,000 typewriters, of which 775,000 were American. In ordinary times, every other typewriter we make goes to some foreign customer.

The experts have also visualized the typewriter of to-morrow. Again, it will be what people want. Already business men are beginning to ask: "Why should we use muscle power to press down keys when there are plenty of electric motors to do such work?" The experts say that eventually typewriters must be electrical—that is, the operator will simply touch a key and a motor will do the work of printing the letter. Blickensderfer, who invented the first real portable typewriter, also built a promising electrical machine in the early years of this century. But it was never widely used. The machine was complex and costly. The electric typewriter must be reasonable in price. It is sure to come at the right time, because it will save human strength, increase writing-speed, and be particularly good at making carbon copies. When electricity operates the mechanism, twenty or thirty copies will be possible. To do this, however, the machine must write flat and not on a roller, for which reason the experts believe that flat writing will characterize the typewriter of to-morrow. But these are still guesses, more or less—we shall have to wait and see.

Here at the end, there is just room to say a word or two about typewriter speed and accuracy. Twenty years ago rival manufacturers started a yearly contest for typists, each hoping to prove that his machine would write faster than any other. The winners began with seventy words a minute, steadily growing faster year by year until now the record is 143 words a minute—which is faster than most people can read a book aloud. To get speed, you must have a well-built machine. It has been figured that one of these champion typewriters, writing 143 words a minute for a whole hour, touches the keys about twelve times a second. But while the typewriter must make twice as many motions as the typist, because the type-bars have to move back as well as forward, and its carriage also moves, close study of the work of the champions in these contests often shows not a single mechanical error.

Father Sholes could certainly have appreciated that!

CHAPTER III

SENDING MESSAGES AND PICTURES OVER A WIRE— THE STORY OF THE TELEGRAPH

EARLY in the nineteenth century a fifteen-year-old lad, the son of a London music-teacher, saved all his pennies until he was able to purchase a small, dry volume describing the electrical discoveries of the Italian, Alessandro Volta. The book was written in French, and the boy had to save more pennies in order to get a French-English dictionary. Before long he was able to read of Volta's experiments and, with the help of his elder brother, began to practise them. Copper plates for his home-made battery were absolutely necessary, and pennies were now very scarce. One day a happy inspiration caused him to make the copper pennies themselves serve the purpose, and his battery was in operation.

Such was the introduction to electrical science of Sir Charles Wheatstone, the inventor of the English telegraph. As a young man he had won distinction by his experiments with sound. By 1834 this work brought him an appointment to the chair of experimental physics in King's College, London. Here he continued his experiments with sound; but his most important result at this time was his measurement of the velocity of an electric current. At length there came to him in his laboratory an army officer home on furlough, William Fothergill Cooke, who was engaged on the invention of a telegraph. Cooke, lacking the scientific knowledge necessary to complete his invention, appealed to Wheatstone for assistance. Wheatstone also was experimenting with the telegraph, and the two entered into a partnership. It resulted in the invention of the five-needle telegraph in 1837.

The telegraph of Wheatstone and Cooke consisted, at the receiving end, of a loop of wire, within which was suspended a magnetic needle. By closing the circuit the needle could be deflected to the right or the left depending upon the direction in

which the current flowed. Five separate circuits and needles, together with a sixth return circuit, were required. By 1845 Wheatstone had reduced his system to a single-wire circuit. The repeated deflections of the needle were made to spell out words by pointing to letters on a dial. Although much inferior to the Morse telegraph—invented about the same time—Wheatstone's system was used in England for many years.

As with other great inventions the attitude of the public toward the telegraph was cool; people regarded it as a new-fangled complication. It required a dramatic incident to bring it into prominent notice, and although the story has frequently been told it is worth repeating.

Shortly after the telegraph had been installed over thirteen miles of the Great Western Railway, a mysterious death occurred in one of the outlying districts of London. A woman was found dead in her home. At an early hour of the same morning a man had been observed to leave the house and take the slow train for London. To effect a quick capture, some one thought of the telegraph, and immediately the operator telegraphed a description of the man to the police in London. The murderer was dressed in the garb of a Quaker, but since the telegraph code contained no signal for the letter Q the operator began to spell the word "kwaker." The London operator asked to have this repeated and continued to do so until a boy suggested that the whole message be sent. When this was done, its meaning at once became clear. The man was arrested as he stepped off the train and at his trial confessed to the crime. The incident quickened public interest; the value of the telegraph had been demonstrated.

How Morse, the Artist, Began

It is surprising that the inventor of the modern telegraph was a well-known artist who had very little training in science. Samuel Findley Breese Morse, son of a Congregational minister, was born in 1791 at Charlestown, Mass., not far from the birthplace of Benjamin Franklin. He came from sturdy Puritan ancestors, and was educated at Andover and Yale. At college Morse came under the influence of Professor Jeremiah Day, one of the foremost men of science of his time. Morse became in-

terested in the experiments in electricity. We find in his notebooks this statement: "If the electric circuit be interrupted at any place the fluid will become visible." Later Morse asserted that it was this "crude seed which took root in my mind, and grew into form, and ripened into the invention of the telegraph."

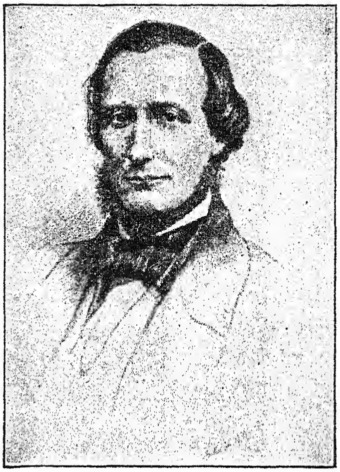
At an early age Morse displayed a keen interest for painting. When a mere lad he painted water-colors. In college he turned this ability to account by painting miniature portraits which he sold to his fellow students at five dollars apiece. Before leaving Yale in 1810 he completed a painting of the "Landing of the Pilgrims," and at graduation decided to devote his life to art. To this end he became a pupil of Washington Allston, one of the best-known American painters of his day, and in 1811 sailed with him for England. In London he was admitted to the Royal Academy, and that brilliant artist, Benjamin West, advised and befriended him.

Morse remained four years in England, making the acquaintance of some of the most notable men of his time and winning marked success in his chosen profession. During this time he won a gold medal for his work in sculpture and in 1813 exhibited at the Academy a huge "Dying Hercules," which was classed among the best twelve paintings there. But he had already stayed abroad a year longer than his allotted time; his funds were gone, his clothes threadbare. In 1815 he returned to America, where his fame had preceded him. The people of Boston flocked to see his work, and its cultured society gave him a most cordial welcome. But no one would buy his paintings, and poverty stared him in the face. Morse, supremely interested in the big things of art, was now compelled to eke out a scanty living by painting portraits.

After three miserable years in Boston, his uncle invited him to Charleston, South Carolina. There he succeeded as a portrait-painter and soon accumulated $3,000. With money in his pocket and many commissions, Morse went to Concord, New Hampshire, and married Lucretia Walker. He returned to Charleston, but eventually left for New York, where he and other artists founded the New York Drawing Association, of which organization he was elected president. This led, in 1826, to the National Academy of the Arts of Design. Morse deliv-

ered lectures on "The Fine Arts," and as president of the National Academy enjoyed considerable popularity. His father and mother and his wife had died, and, in 1829, Morse re-

SAMUEL F. B. MORSE.



CYRUS W. FIELD.

turned to Europe to spend three years in the art centres of Italy and France.

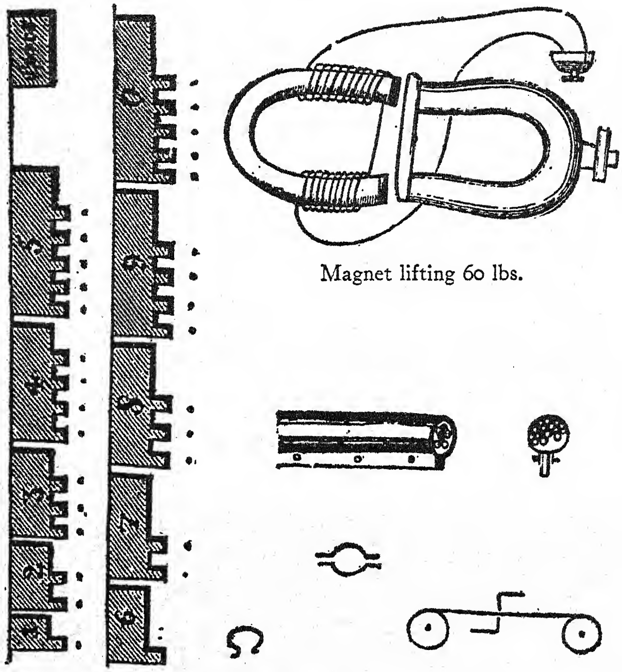
The Idea of the Telegraph Flashes upon Morse

For all his passion for art, Morse was destined to make his name in another direction and to throw his energy, heart, and soul into a work diametrically opposed to painting.

In 1832 he was returning from Europe on the packet ship *Sully*. In the cabin of the ship Doctor Charles T. Jackson, of Boston, exhibited an electromagnet which he had obtained in Paris. To the passengers, Jackson described some experiments which he had seen Ampère perform. Morse at once recalled his early studies in electricity and, upon inquiry, learned that Faraday considered the speed of electricity as instantaneous. Totally ignorant of any previous work upon the subject and, indeed, of any other similar invention, Morse, with the insight of true genius, conceived the idea of the telegraph. Could an electrical mechanism be devised for transmitting signals and

messages from a distance? Asking himself that important question, Morse was definitely launched upon a project which finally resulted in his invention of the modern telegraph.

Throughout the remainder of the long and tedious voyage

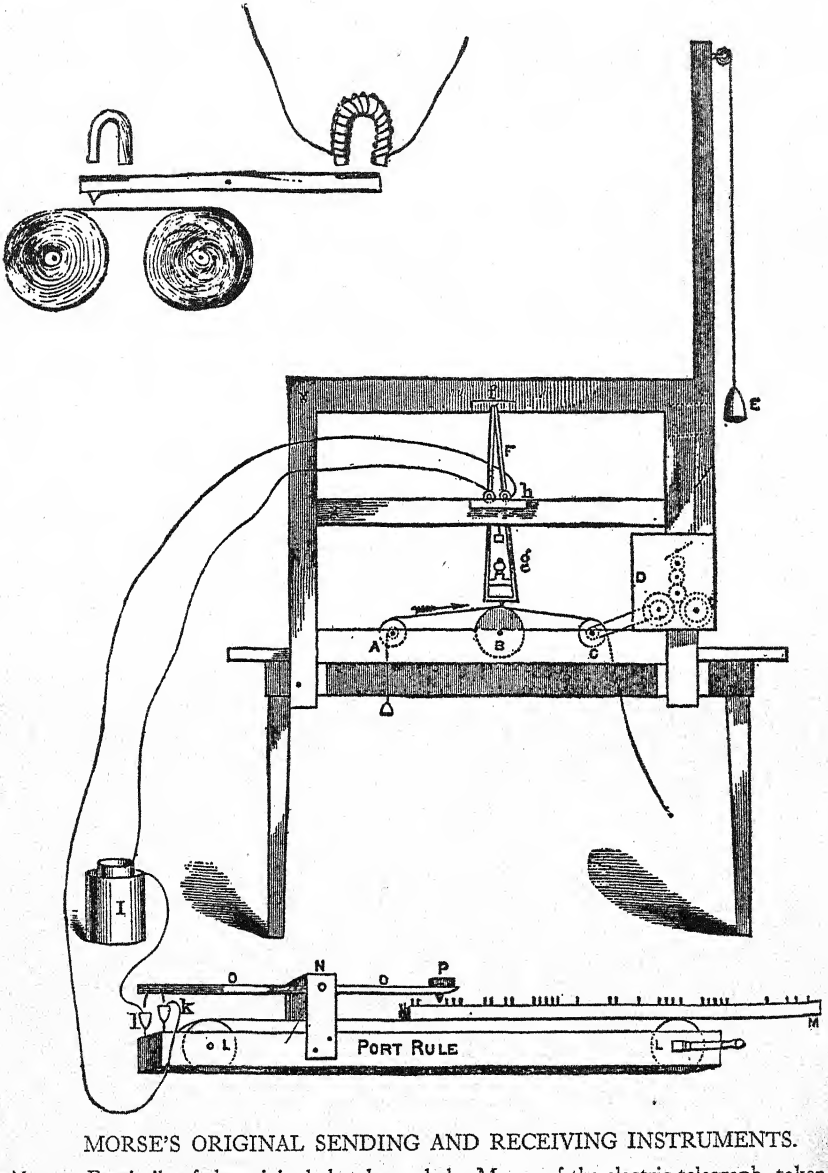


From "Life of S. B. Morse," by S. I. Prime.

SKETCHES FROM MORSE'S NOTE-BOOK.

Samuel F. B. Morse was a passenger on the packet-ship *Sully* which sailed from Havre on October 1, 1832, for New York. At dinner one evening he conversed with a Doctor Jackson on the transmission of electricity over a wire. A few days later he made rough drawings of an electric telegraph. These are not the drawings of his earliest instruments. They bear, however, a close resemblance to those which he exhibited on the packet-ship *Sully*.

Morse busied himself with plans for his great invention. The pages of his sketch-book were no longer utilized for artistic impressions; instead, crude drawings of telegraph instruments took their place. One of the distinctive features of his proposed system was an automatic receiver for recording the messages. Already he had pictured in his mind an electromagnet with its armature, a moving tape, and a system of dots and dashes.



MORSE'S ORIGINAL SENDING AND RECEIVING INSTRUMENTS.

Above—Facsimile of the original sketch, made by Morse, of the electric telegraph, taken from his note-book.

His enthusiasm knew no bounds. As he landed in New York, he remarked to the captain: "Should you hear of the telegraph one of these days as the wonder of the world, remember that the discovery was made on board the good ship *Sully*."

The one great thought that now dominated every waking moment of Morse's life was to perfect his telegraph. For three years he made little progress. Beset with poverty, having no fixed place of abode, very little scientific knowledge and less mechanical skill, the obstacles in his way seemed almost insurmountable.

In 1835 his renown as an artist gained him an appointment as professor of the literature of arts and design in the newly established University of New York. Here he came into close relationship with Leonard D. Gale, professor of chemistry. Gale gave him valuable assistance, especially in the making of batteries. But progress was slow. Apparatus and supplies were exceedingly difficult to obtain in those days, and Morse was compelled to make his electromagnet himself. From a blacksmith-shop he obtained a soft iron core, bent to the shape of a horseshoe. Insulated copper wire was unknown, so he bought a few yards of bare wire and insulated it by methodically and painstakingly winding cotton around it.

One of his first disappointments was the discovery that the electric current in his line would not work the armature of the electromagnet. He had used only a few turns of rather coarse wire. But at this point Gale acquainted him with Professor Joseph Henry's remarkable work in electromagnetism.

Henry had increased the sensitiveness of an electromagnet to a marvellous degree by using many turns of fine wire; indeed, he almost anticipated Morse in the invention of the telegraph. In his laboratory at the Albany Normal School, Professor Henry had strung a mile of wire. At one end of the circuit he placed a battery and key and at the other an electromagnet. By pressing the key he caused the armature of the magnet to strike a gong and thus give signals by sound. Being a pure scientist, however, Henry was not interested in the practical development of his discovery.

After he had learned of Henry's discoveries, Morse was able to correct the faults of his apparatus. Soon he had a crude

model in operation in the laboratory of the university. The picture printed on page 291 shows its general form. Upon a wooden frame nailed to a table he mounted the electromagnet and clockwork to move the tape, and to the pendulum he attached both the armature of the magnet and the marking-pencil. When the circuit was made and broken by a special device, the pendulum swung back and forth so that its pencil marked the moving tape, and the "signals" were read off.

This was a great step forward; but new difficulties retarded the invention. It is impossible to send water through a pipe for miles without great pressure. It is equally impossible to send an electric current through a wire for miles without the pressure we now call "voltage." In telegraphy weak currents were used, and in sending an electric signal through great lengths of wire the effect at the end of the long wires was so feeble as to be practically imperceptible. To overcome this defect Morse invented what is called a relay. If the invisible current would not actuate a heavy receiver, at least it could be made to operate a weak spring armature of a very sensitive electromagnet. A slight pull of the throttle of a powerful locomotive starts the wheels moving; a feeble current of electricity will affect the magnet of a relay in the same way. In a word, the relay acts like the throttle of a locomotive, and thus moves local electrical mechanism.

Morse now had all the elements of the modern telegraph. This was in 1837 and in that same year Congress directed the secretary of the treasury to inquire into the desirability of establishing a system of telegraphs in the United States. This action fired Morse with still greater enthusiasm, and he determined to bring his invention to the attention of the public. But, without funds and influence, he was helpless.

Morse Meets Alfred Vail

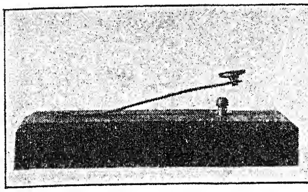
About this time Morse, while demonstrating his apparatus to some visitors, made the acquaintance of a young man named Alfred Vail, whose father, Judge Stephen Vail, was well known, prosperous, and the owner of the Speedwell Iron Works at Morristown, New Jersey. Young Vail immediately foresaw the tremendous commercial possibilities of the tele-

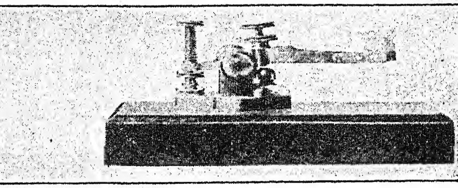
graph, and he suggested that Morse accept him as a partner in the enterprise. This was the very assistance that Morse needed, and he was only too glad to grant the request; particularly as the elder Vail supplied $2,000 for additional experiments and offered his foundry as a workshop. Alfred Vail, possessing considerable mechanical ability, at once took off his coat and went to work with all the enthusiasm of youth. He made many improvements in Morse's instruments and very largely worked out the Morse code of dots and dashes.

The ardor of Judge Vail, however, soon began to cool. Ridiculed by his acquaintances for the support that he had given to this rash scheme, he now regretted his generosity. But at last in January, 1838, the telegraph was complete. Vail summoned his father to the workshop and the judge wrote this message: "A patient waiter is no loser." He asked his son to send it to Morse, who was at the receiver, stating that if he could do so he would be satisfied. The test was a complete success. The invention of the telegraph was achieved.

The Work of Publicity

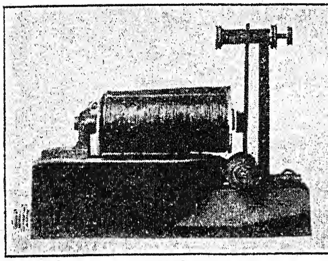
Often more difficult than perfecting a new invention is the task of properly introducing it to the public. So it was with the Morse telegraph. Scepticism had to be overcome, financial support secured, and the public educated to a realization of the value of the telegraph. When placed on exhibition in New York and Philadelphia, no one seemed interested. As, later, they were to say of the telephone, the telegraph was only a "scientific toy." But Morse's patent was filed as a caveat at the United States Patent Office in 1837, and in December of the same year he appealed to Congress for aid to build an experimental line, pointing out that the chief purpose of his invention was the public welfare and not private gain. He took his telegraph to Washington and finally succeeded in interesting the Committee on Commerce of the House of Representatives. The chairman of the committee, Francis O. J. Smith, resigned his seat in Congress in order to become an active partner in the enterprise. In 1842, a bill was introduced appropriating $30,000 for the building of an experimental line between Washington and Baltimore.

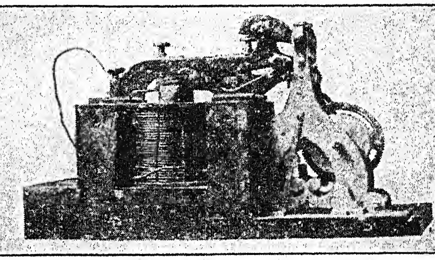




FIRST FORM OF KEY.

IMPROVED FORM OF KEY.



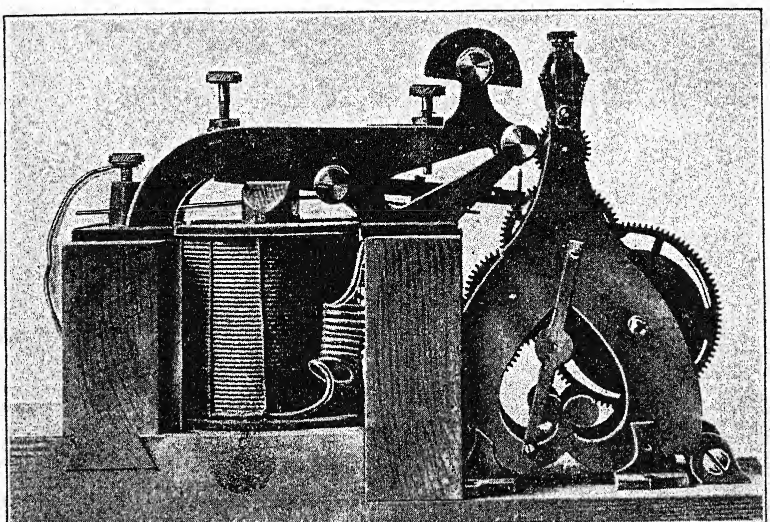


EARLY RELAY.

FIRST WASHINGTON-BALTIMORE INSTRUMENT.

The two keys and the relay are in the National Museum, Washington.

The Washington-Baltimore instrument is owned by Cornell University.



ENLARGED VIEW OF MORSE REGULAR, USED ON FIRST BALTIMORE AND WASHINGTON LINE.

STAGES IN THE EVOLUTION OF MORSE'S TELEGRAPH.

Morse now seemed to be on the flood-tide to success. A company was formed for the promotion of the enterprise, and Morse and Smith hurried away to Europe to secure patents in foreign capitals. But stormy days were ahead. Morse was entirely unsuccessful in his efforts abroad, and returning home he found Doctor Jackson claiming a share in his invention and Congress wholly indifferent to the passage of his bill. To add to his difficulties Morse faced the bitterest poverty. The Vails were unable to give him further assistance and his other associates left him to fight the battle alone.

In court, Morse proved the absolute falsity of Doctor Jackson's claims, and by taking a few pupils in painting and charging them a small fee managed to keep from starving. While in Paris he had learned from Louis Daguerre the new process of photography, and with Doctor John W. Draper of the university he was the first to introduce daguerreotypes in America. This, too, was unprofitable.

The following incident, told by General Strother of Virginia, one of his art pupils, describes the poverty of Morse during those dark days. Strother's second quarter's pay was due and his remittance from home had not arrived. One evening, Morse approached him and said courteously:

"'Well, Strother, my boy, how are we off for money?'"

"'Why, professor,'" I answered, "'I am sorry to say that I have been disappointed, but I expect a remittance next week.'"

"'Next week,'" he repeated sadly, "'I shall be dead by that time.'"

"'Dead, sir?'"

"'Yes, dead by starvation.'"

"I was distressed and astonished. I said hurriedly: 'Would ten dollars be of any service?'"

"'Ten dollars would save my life. That is all it would do.'"

"I paid the money, all that I had, and we dined together. It was a modest meal, but good, and after he had finished, he said:

"'This is my first meal for twenty-four hours. Strother, don't be an artist. It means beggary. Your life depends upon people who know nothing of your art and care nothing for you. A house dog lives better, and the very sensitiveness that stimulates an artist to work keeps him alive to suffering.'"

At length, February 23, 1843, Morse's bill for an appropriation of $30,000 was again introduced in Congress. The project suffered the severest ridicule. Many members regarded it as the visionary scheme of a "crank" and were afraid to go on record as even favoring it. Defeat seemed certain. But the bill did pass the House by a narrow margin of eight votes, and it went to the Senate. On the last night of the session Morse anxiously waited in the gallery. One of the senators came up to him and declared: "There is no use of your staying here. The Senate is not in sympathy with your project. I advise you to go home and think no more about it."

Broken in spirit, dejected, his last hope shattered, Morse returned to his boarding-house, and, after paying his bill and buying a ticket to New York, all the money he had to his name was thirty-seven and a half cents. But the next morning while he was at breakfast he received a visit from a young lady. Coming toward him with a smile, she exclaimed:

"I have come to congratulate you!"

"What for, my dear friend?" asked the professor of the young lady, who was Miss Annie G. Ellsworth, daughter of his friend the commissioner of patents.

"On the passage of your bill."

The professor assured her it was not possible, as he remained in the senate-chamber until nearly midnight, and it was not reached. She then informed him that her father was present until the close, and, in the last moments of the session, the bill was passed without debate or revision. Professor Morse was overcome by the intelligence, so joyful and unexpected, and gave at the moment to his young friend, the bearer of these good tidings, the promise that she should send the first message over the first line of telegraph that was opened.

"What Hath God Wrought?"

Morse and his partners now took up the work of construction. Ignorant of the difficulties confronting them, they unfortunately decided in favor of underground wires. After they had exhausted more than two-thirds of the appropriation the insulation proved defective and the underground system had to be abandoned. Luckily, Ezra Cornell, later to be the founder

of a great university, was associated with them. Upon his advice they hurriedly strung the wires overhead, insulating them by the necks of bottles thrust through holes bored in the tops of poles. This saved the situation.

On the day chosen for the public exhibition, May 24, 1844, Annie Ellsworth handed to Morse, sitting at the transmitter in the Supreme Court room of the capitol, the words: "What hath God wrought?" This was immediately transmitted to Vail in Baltimore, who in a few moments sent back the same message, and the invention of the telegraph passed into history.

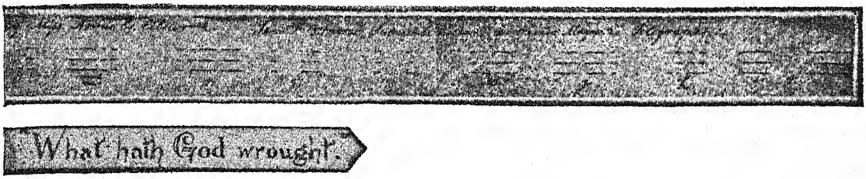
The public's interest remained lukewarm. As with Wheatstone and his English telegraph, something sensational was needed to bring the new invention into prominent notice and favor. It so happened that the national Democratic convention was then in session at Baltimore. Vail learned that Silas Wright, of New York, had been nominated for the vice-presidency, and telegraphed the news to Washington. Morse received and handed the telegram to Wright, who was in the senate-chamber. Wright declined the nomination, and Morse instantly telegraphed back his refusal. The members of the Baltimore convention, on being handed the despatch, would not believe, and they adjourned until a committee was sent to Washington to report truthfully on the matter. Complete verification of the telegraphic message convinced the American people of the immense importance of telegraph service.

Morse offered his invention to the government for $100,000, but although they voted $8,000 for maintaining the original telegraph line, they declined to commit themselves further. Disappointed, Morse then organized the Magnetic Telegraph Company and set about securing funds for the construction of a line from New York to Philadelphia. It was slow but sure work. Little by little telegraph lines began to multiply. They spread like a network over the Eastern States. Many companies sprang up. Morse's patents were infringed and he was compelled to file many lawsuits for his rights, which the courts always upheld. There was plenty of telegraph business now, yet no one seemed to be making money in it.

In 1856, Hiram Sibley organized the Western Union Telegraph Company, which some one likened to "collecting all the

paupers in the State and arranging them into a union so as to make rich men of them." The company succeeded, and a line was put through to the Pacific coast. The profits were enormous, and through his patents Morse became a wealthy man. He was honored with orders, decorations, and medals by the leading nations of the world. He died in 1872, full of years and rich in the esteem of his fellow men.

It was early discovered that messages could be read simply by listening to instead of seeing the clicking of the armature of



THE FIRST MESSAGE SENT BY MORSE.

the electromagnet. Morse had considered the automatic recording device of his receiver the most important feature of his invention. Yet reading by sound was so much simpler and easier that neither threats nor penalties could prevent the practice. Vail then devised the modern type of sounder, and also made many other changes in telegraph apparatus.

The first great improvement was made in 1858 by J. B. Stearns, of Boston. In that year he introduced duplex telegraphy; a system by which two messages, one in each direction, might be sent over a single wire at the same time. This he accomplished by arranging relays at each end of the line which would in each case respond to incoming signals, but not to outgoing signals. In that way a message could be received, and another sent, at the same time over the same wire.

Edison and the Telegraph

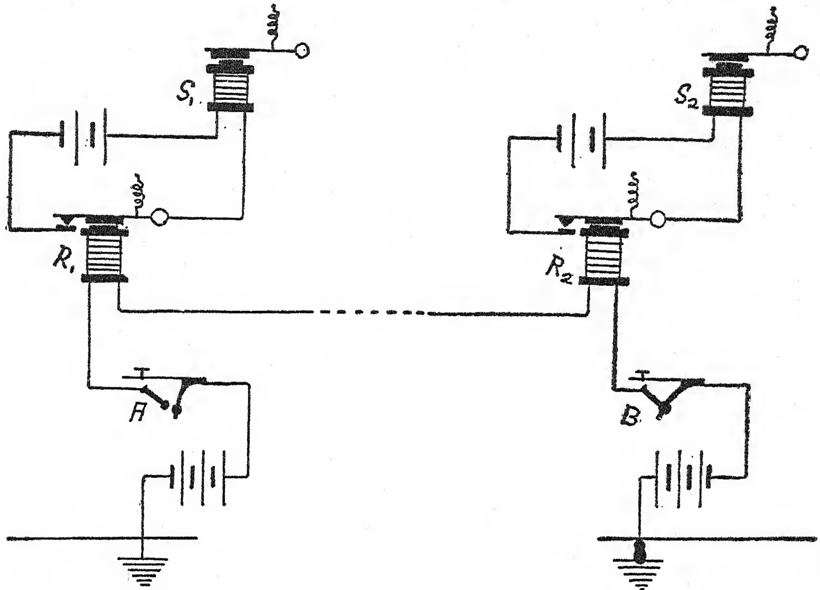
One of the "brass pounders" to whom Morse's invention gave employment was Thomas A. Edison. A telegraph operator with his extraordinary inventive gifts would naturally introduce improvements. One of his earliest inventions was a duplex telegraph of his own. In 1869 he went from Boston to

New York. Arriving there he borrowed a dollar to tide him over until he could get a position as an operator. While waiting he spent much of his time about the offices of the Gold Indicator Company in order to study their complicated system of indicators and transmitters for distributing to the various brokers' offices of the city the current stock quotations.

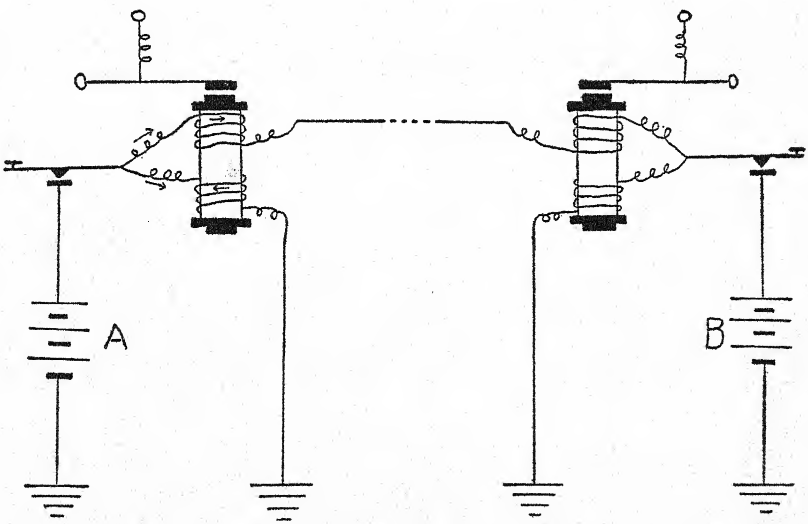
Edison had been waiting for three days, when an opportunity occurred to test his genius. As usual, he was sitting in the company's office, when suddenly the complicated mechanism which controlled the outgoing lines came to a dead stop. Soon more than 300 boys, one from every broker's office on the street, came crowding into the room. Pandemonium reigned and the man in charge lost his head. Edison quietly walked over to the instrument, studied its parts for a moment, and located the trouble. A contact spring had broken off and fallen between two gear-wheels, thus stopping the movement.

Doctor Laws, the superintendent of the company, arrived and asked the foreman what was the cause of the trouble; but the man was unable to explain. Edison then volunteered to fix the instrument, and was told to do so at once. Seemingly by magic, he deftly removed the spring, adjusted it, and set the wheels moving again. Doctor Laws called Edison into his office and offered to put him in charge of the "tickers" at $300 a month. Almost overcome with astonishment and delight, Edison accepted the position. To one who just lately had been compelled to borrow a dollar, the salary of $300 a month was princely; but Edison, instead of taking it easy, worked no less than twenty hours a day trying to improve the stock-tickers of that time.

A stock-ticker is a telegraph instrument which automatically records on a moving tape the quotations of the various stocks listed on the exchange as rapidly as they appear. A man in the exchange sits at a keyboard, circular in form and carrying upon it all of the letters and figures used in stock quotations. As he reads the quotations, he perforates a moving tape by striking the keys just as in operating a typewriter. This tape passes through a transmitter which operates a large number of line relays and sends the signals to the tickers in the brokers' offices, and also to distant cities.



SIMPLE TELEGRAPH SYSTEM.



DUPLEX SYSTEM OF TELEGRAPHING.

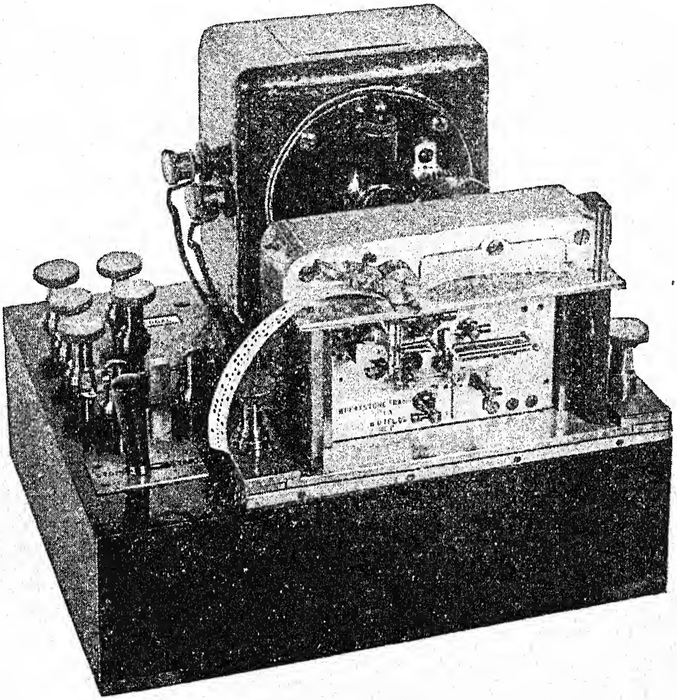
After Edison had taken out patents on a large number of inventions covering improvements on the tickers, General Lefferts the president of the Gold and Stock Telegraph Company, offered to buy his patents. Edison had intended to ask \$5,000 and, if necessary, to come down to \$3,000. But, when the psychological moment arrived, he did not have the nerve to name such a large sum, so he asked Lefferts to make him an offer. The president of the telegraph company suggested the sum of \$40,000. "This caused me," said Edison, "to come as near fainting as I ever got. I managed to say that I thought it was fair." After that he opened laboratories in Newark.

Edison Sends Four Messages at a Time over the Same Wire

Edison soon became involved in a multitude of inventions, but one of his chief problems was an automatic and multiplex telegraphy. George Little, an Englishman, had invented a system of automatic telegraphy which worked well on short lines but did not meet the exacting requirements of long-distance telegraphy. Accepting Little's principle of mechanism, Edison converted it into a highly satisfactory system. In a short time he was sending and recording 1,000 words per minute between New York and Washington, and 3,500 words to Philadelphia. Like many other automatic systems, it included a hand-punch for perforating a moving tape which was passed through an automatic transmitter. Wherever a hole came in the tape an electric contact was made, and an "impulse" sent to the line. At the receiving end an automatic recorder printed the message on chemically prepared paper. Edison improved every part of the system, and for some time it was in active use on American lines.

Then came Edison's quadruplex telegraphy, which enabled him to send over a single wire four messages at the same time, two in each direction. In this system Edison combined two sets of instruments. One set would respond only to a change in the strength of the line current, while the other set would respond only to a change in the direction of the current. Although this system was sensitive to bad weather conditions and was so delicately balanced as to be easily thrown out of adjust-

ment, yet it was of immense importance in extending telegraph service. It has been estimated that in America alone quadruplex telegraphy has accomplished a saving of from \$15,000,000 to \$20,000,000 in line construction.



MODERN AUTOMATIC TAPE TRANSMITTER.

Typewriting by Telegraph

As early as 1846 Alexander Bain, a Scotchman, invented an automatic transmitter employing a perforated strip of paper. At the receiving end the dots and dashes were recorded on a rapidly moving tape of chemically prepared paper by means of an iron stylus.

The first real printing telegraph, one which actually printed the message in Roman type, was invented by David E. Hughes, of Kentucky, in 1855. Hughes was a master of music and a born inventor. His ambition was to invent a telegraphic type-

printer. Before he could accomplish such a thing it was necessary to keep his transmitting and receiving instruments in perfect unison with each other. For a long time this had baffled him. Finally, two darning-needles borrowed from an old lady in the house where he lived gave him the clue. He arranged a system of equally timed vibrating needles or rods, and in this way solved his problem. Hughes's printing telegraph was used for a time in this country, but was gradually superseded by other systems. In England and Europe it still has a very wide application.

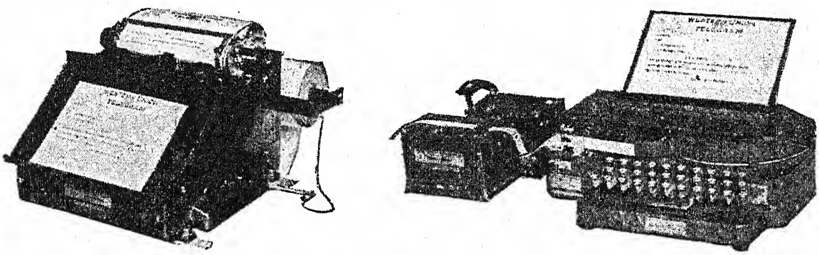
Professor Henry A. Rowland, of Johns Hopkins University, invented a printing telegraph which could send eight messages simultaneously over a single wire. It was a beautiful piece of work, but unfortunately was not adapted to the electric requirements of existing lines. It embodied, however, a principle which has been frequently utilized in other systems. The transmitter consisted of a keyboard, like a typewriter, and the recording instrument printed the message exactly as a typewriter does. The recorder, too, was under the perfect control of the transmitting operator. The pressing of any key sends an "impulse" over the line which automatically prints on a sheet of paper the corresponding letter. As in the ordinary office typewriter, the telegraph operator also spaces, makes numerals, and shifts the carriage in either direction and from line to line. These features have now become standard in many systems.

Other men who have invented widely used systems more or less similar to those already described are Baudot, Buckingham, Murray, and Delany. The most remarkable system is the Pollak-Virag telegraph. A tape is punched with a double row of holes and passed through a transmitter in the usual way. The impulses sent over the line are made to operate a delicately hung mirror which can swing in every direction. Upon this mirror is thrown a beam of light from an incandescent lamp. As the mirror swings the beam is reflected to a sensitized sheet of paper. Thus the signals in the form of light are actually photographed. In its latest form, this telegraph has been made to record its messages in legible writing. The speed of transmission is over 100,000 words an hour. It is impossible to predict the future of such an instrument.

The Modern Multiplex

The multiplex system now in use on the Western Union lines sends eight messages on a single line at the same time, and prints them in typewritten form ready for distribution. Four messages are sent in each direction, and eight operators are required at each end of the line, four to send and four to receive. This system is an adaptation of the Delany multiplex.

As you enter a large Western Union Telegraph office you see row after row of these machines in operation. The click-click



(Left) A PAGE MULTIPLEX PRINTER.
(Right) AUTOMATIC TELEGRAPH PRINTER AT RECEIVING END.

of the transmitters mingling with the hum of vibrating tuning-forks and rotating motors is almost orchestral. To and fro, from city to city, nation to nation, shuffle messages. All are important; the very purpose of the telegraph is to save time.

Four strips of moving tape are perforated by operators at typewriter keyboards, after which the strips pass through the respective transmitters. The electric "impulses" are sent to the line through the segments of a rotating metal disk, over which moves a conducting arm or brush. There are twenty of these insulated segments, five for each transmitter, and at each rotation one letter is sent to the line from each instrument. At the receiving end of the line there is another disk exactly similar to the first and rotating in exact unison with it. Therefore, as the impulse from a particular transmitter is sent to the line, the corresponding receiving instrument is at that same instant also in connection with the line. These four impulses are sent to the line in rapid succession and received at the

other end in perfect sequence. As already stated, four messages are also being sent from the opposite direction at the same time. The speeds of the motors which operate the rotating disks are controlled by vibrating tuning-forks of exactly the same pitch.

Since each operator can send from forty to fifty words a minute the maximum speed for eight is from 320 to 400 words. The actual speed of the automatic systems, depends upon and is limited by the speed with which an operator can perforate a tape. High speeds are obtained only when the tape has been prepared in advance by a large number of operators. There are mechanisms for very rapid sending and receiving, but as yet there is no magic method of preparing the tape.

Very recently, as described in the chapter on the telephone, it has been made possible to send as many as forty telegraph messages over a single wire at the same time. This system is adapted only to long-distance transmission and has not yet come into extensive use. There is no doubt, however, that it holds great promise for the telegraph service of the future.

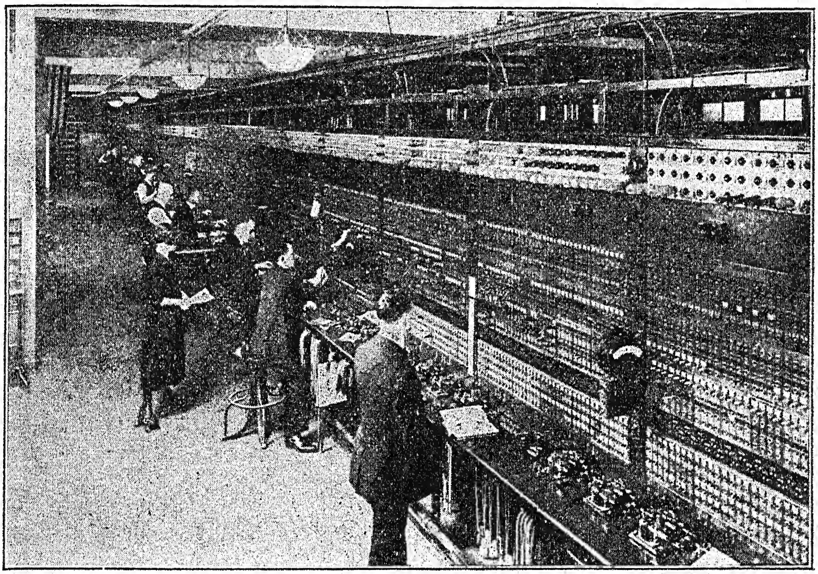
Elisha Gray Invents His Harmonic Telegraph

One of the most interesting figures in telegraph history is Elisha Gray. Of Quaker parentage, educated at Oberlin College, with a genius for invention coupled with marked mechanical ability, he early turned his attention in life to electricity. Gray became one of the original promoters of the Western Electric Company and from his many inventions amassed a fortune. Many of these were telegraphic devices.

His most interesting invention was the harmonic telegraph. At the sending end Gray placed a number of electromagnets, each one of which kept in constant vibration a tuning-fork of definite pitch. These vibrating tuning-forks, each of a different pitch, were made to interrupt the line current and therefore sent out a complex combination of impulses. At the receiving end, the line current was passed about an equal number of electromagnets, over each of which was placed a steel reed. Each reed was so tuned that it would respond and be thrown into vibration by one and only one of the forks at the transmitting end. Therefore, Morse signals sent through the contact points

of any one of the vibrating forks were received only in that circuit whose reed vibrated at the same rate. Gray sent as many as nine messages over a single wire. The system has been since improved so that it sends twelve.

Gray's "telautograph" was one of the first of the facsimile telegraphs. He made a pencil in the hand of the sender elec-



CHICAGO SWITCHBOARD, WESTERN UNION OFFICE.

trically operate another pencil at a distance and, therefore, reproduce handwriting.

Telegraphing Pictures over Wires

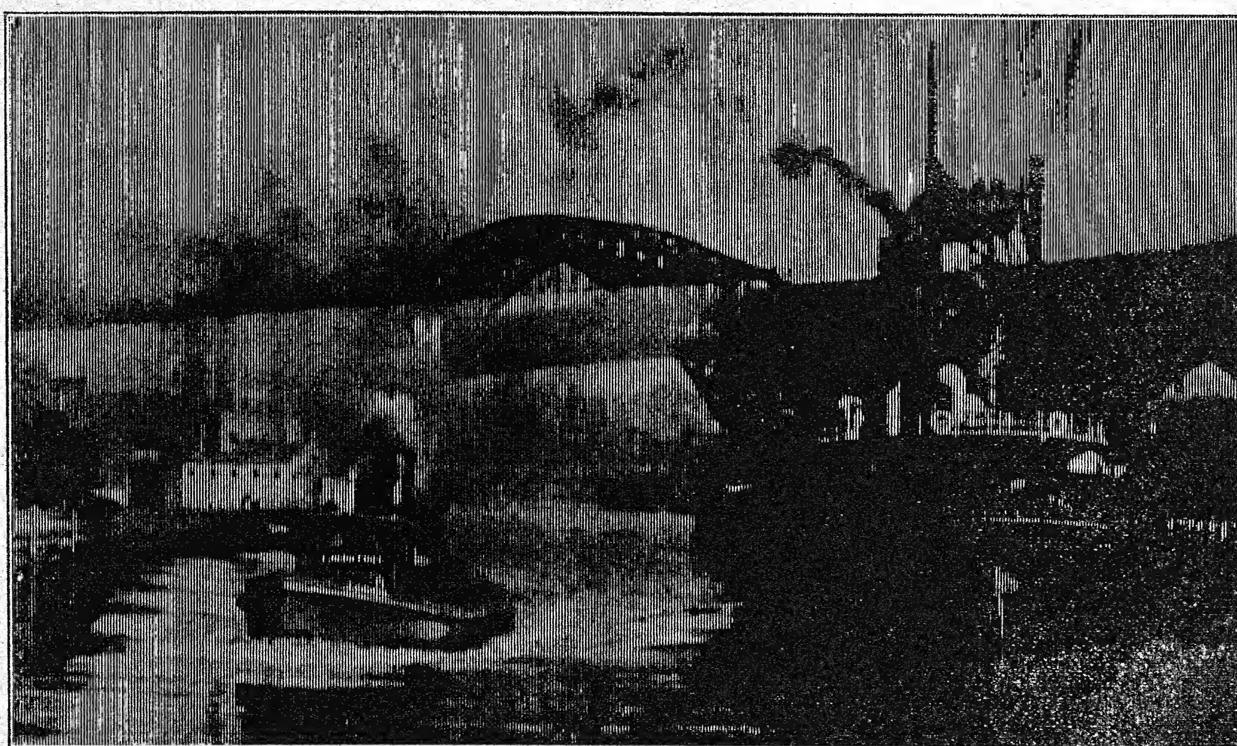
Although the art of telegraphing pictures is still in the experimental stage, very remarkable results have been obtained. The first successful long-distance photographs were made by Professor Arthur Korn, of Germany, in 1904. Professor Korn took advantage of the fact that the element selenium is electrically sensitive to light, and that its resistance changes with a variation in the intensity of illumination.

Within a glass cylinder, which can both rotate and shift itself in the direction of its length, glows an electric lamp. Around

the cylinder is wrapped the photograph about to be transmitted. It is evident that the rays from the lamp will easily pass through the light portions of the photograph, but not so easily through the dark. By rotating and by shifting the cylinder in the direction of its length, the rays from the lamp will strike every portion of the photograph in its spiral path. The beam from the lamp, of course, passes through only one spot at a time. If that spot is comparatively light or transparent, the beam passes through the revolving cylinder and falls upon the selenium cell. Since selenium varies in conductivity with the amount of light that happens to fall upon it at any given time, the amount of current which passes through an electric circuit in which the selenium is included also varies. At the receiving end is another rotating and shifting cylinder around which a photographic film is wrapped. The electric current is made to open and close a shutter through which the beam of light is focussed upon the revolving cylinder. The operation is clear enough. The selenium cell of the sending instrument is now in the dark, now in the light, depending upon the resistance offered to the beam of light by the different portions of the photograph wrapped around the transmitting cylinder. The current in the line fluctuates with the amount of light that happens to fall upon the selenium cell at any given instant. These fluctuations in turn cause the shutter at the receiving end to open or close, so that more or less light falls upon the rotating or shifting revolving cylinder. Hence the beam of light at the receiving end traces a spiral record on the film, but a record which is now black and now light. Develop the photograph of the receiving cylinder and it is now a duplicate, composed of fine lines, close together, of the picture wrapped about the transmitting cylinder.

In Paris, M. Bélin experimented for a number of years with a different system. He produced a negative in relief which he wrapped about a revolving cylinder over which moved a stylus. The stylus varied the electric current in the receiving circuit with the light and shade of the picture. By a suitable mechanism, Bélin made this changing current vary the intensity of light thrown on the receiving film.

A theoretically old but only recently applied scheme is the



CLEVELAND'S HIGH BRIDGE.

A picture transmitted by wire from Cleveland, Ohio, to New York, on May 19, 1924, by the American Telephone and Telegraph Company. A beam of light passes through a transparent rotating print and, falling upon a photoelectric cell, controls the amplitude of the line current. The line current in turn operates a specially constructed receiving element, the beam from which is recorded on a sensitive film rotating synchronously with the transmitting print.

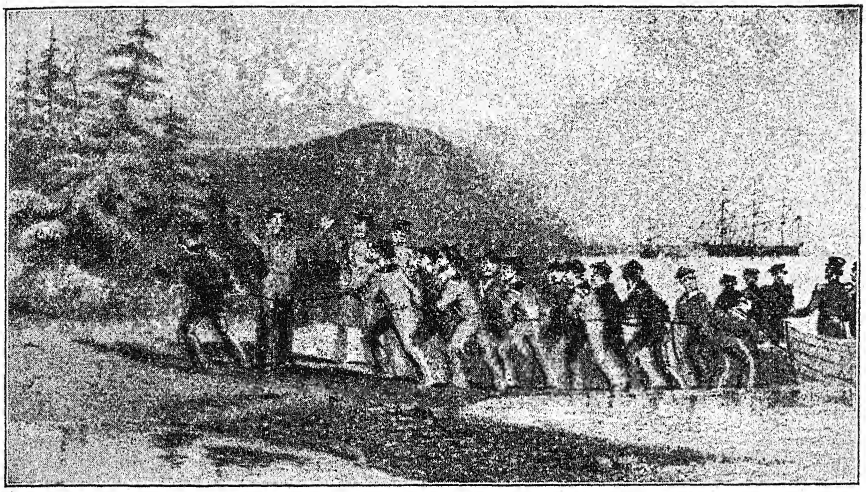
one by which photographs are telegraphed in code. Over the print is placed a transparent sheet of celluloid, marked off in quarter-inch squares. The light and shade of the print is then carefully indicated on these squares by a system of code numbers which are telegraphed to the distant newspaper-office. From this code a black-and-white reproduction of the picture is quickly made for newspaper use. Pictures of the Dempsey-Carpentier fight of July 2, 1921, were thus sent to Los Angeles to be reproduced the following morning: fifty minutes were consumed in telegraphing and an hour and ten minutes in decoding. The same pictures were also cabled to London, and reproduced soon after the event.

Cyrus Field and the Atlantic Cable

Magnificent as the triumph of land telegraphy had been, it was destined to be outdone in the telegraphic conquest of the sea. To the clearness of vision and indomitable perseverance of that little group of pioneers who, against every obstacle of fate and man, accomplished the Herculean task of laying the first Atlantic cable, the world owes a debt of gratitude it can never pay.

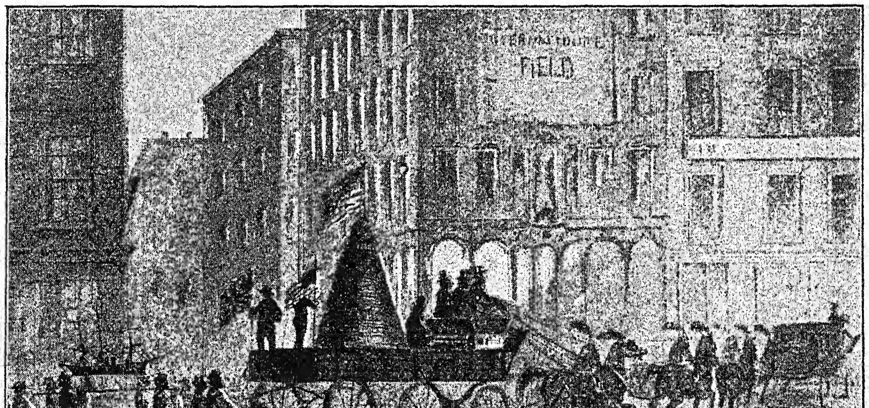
In 1842, the first cable line in America was laid beneath New York Harbor by Morse during those anxious days of waiting for the recognition of his great invention. Another was laid between New York city and Fort Lee in 1845 by Ezra Cornell. In 1850 John Watkins Brett laid the first successful cable across the English Channel. Two years later England and Ireland were connected by cable and, soon after, a cable was laid beneath the North Sea to Holland. Morse, even before he had perfected his original telegraph, with prophetic vision, predicted that some day men would telegraph beneath the Atlantic.

In 1852, an engineer named F. N. Gisborne conceived the idea of connecting by telegraph New York and St. John's, Newfoundland. By this the time of communication between the two continents was to be shortened by two days. Part of the line was to consist of a submarine cable across the Gulf of St. Lawrence. Running out of funds, he applied to Cyrus W. Field, a retired merchant of New York, for financial assistance. Although Field had amassed a fortune, he was still a young



From Valentine's Manual.

LANDING OF THE SHORE END AT TRINITY BAY, AUGUST 4, 1858.

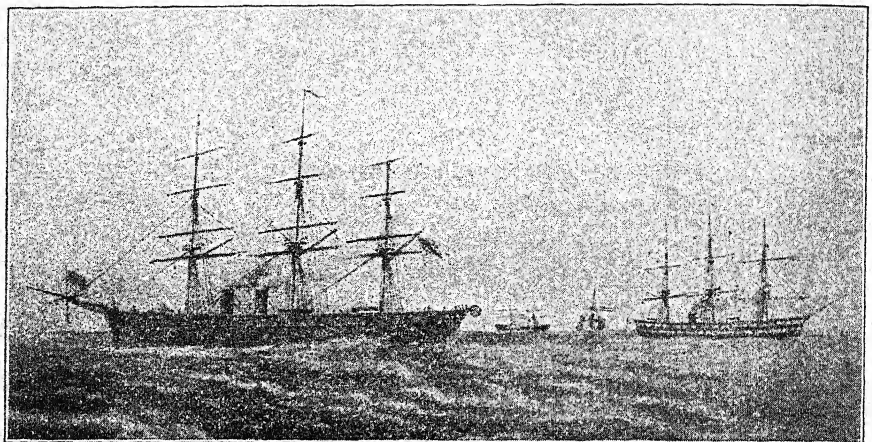


From Valentine's Manual.

SECTION OF THE ATLANTIC CABLE, CARRIED BY ADAMS & COMPANY'S EXPRESS WAGON THROUGH THE STREETS OF NEW YORK.

man, and the project strongly appealed to him. It soon occurred to Field that of far greater importance to commerce was a direct cable joining the Old World with the New; in other words, a cable under the Atlantic. It became Field's great obsession. Seldom has any man been fired with a more contagious enthusiasm or a mightier determination.

He began work immediately. The British and American Governments responded to his appeal for assistance, and vessels from each navy were detailed to make soundings of the ocean bottom between Newfoundland and Ireland. The report was exceedingly favorable, and Morse pronounced the project entirely feasible. Sailing for England, Field organized the Atlantic Telegraph Company, and set about securing financial support. A quarter of the capital he supplied himself and had no difficulty in obtaining the rest. He then enlisted the services of Charles T. Bright, a young Englishman, as engineer for the company; but even more important was the addition of Professor William Thomson (afterward Lord Kelvin) of Glasgow University as an enthusiastic member of the enterprise.



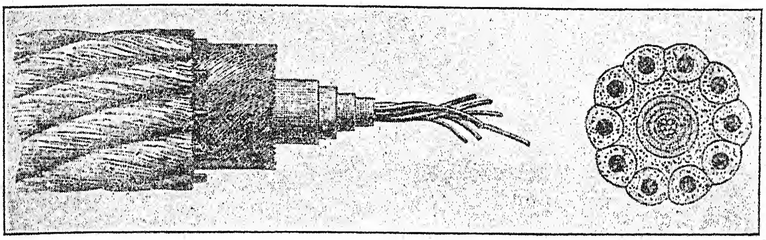
From Valentine's Manual.

THE *NIAGARA*, *VALOROUS*, *GORGON* AND *AGAMEMNON* LAYING THE CABLE AT MID-OCEAN.

The next step was to manufacture the cable. Although the distance to be covered was but 1,640 nautical miles, 2,500 miles

of cable were supplied. It consisted of seven copper wires insulated with the newly discovered gutta-percha, wound about with tarred hemp, the whole sheathed in a casing of heavy iron wires.

To lay the cable England loaned the *Agamemnon*, and the United States the *Niagara*, two of the largest warships then afloat. On August 5, 1857, the two vessels, accompanied by an escort of several smaller ones, steamed away from the Irish



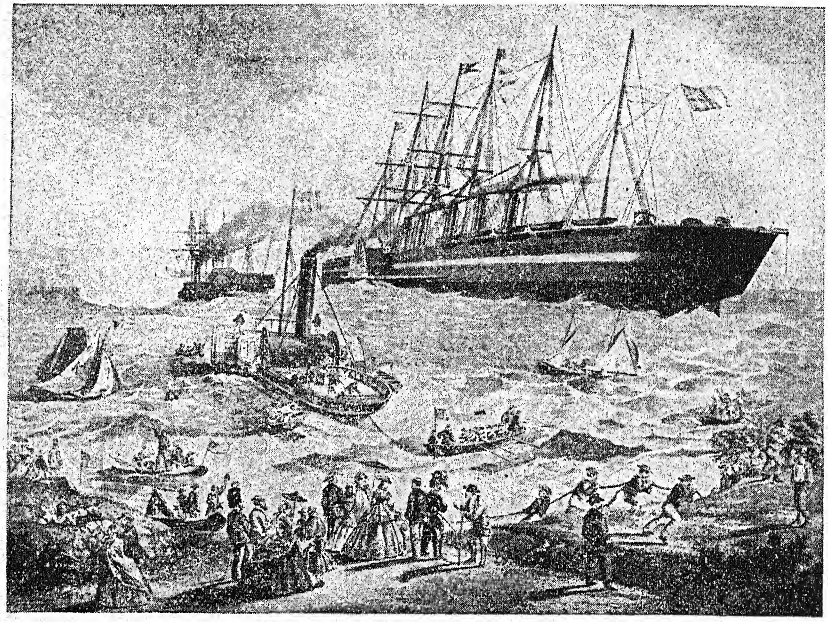
SECTION OF THE ATLANTIC CABLE OF 1866.

coast amid much ceremony and with high hopes for success. For a time all went well. The paying-out machinery on the *Niagara* worked without a hitch. Nearly 400 miles of cable had been laid down. Then, as the stern of the *Niagara* was lifted on a high wave, the cable parted, and could not be recovered. It was terribly disheartening. There was nothing to do but return to port and abandon the enterprise, at least for that year.

A half-million dollars had been lost, and many now believed the task impossible, but a second attempt was made in the following June. Improved paying-out machinery was installed, also a device for automatically releasing the cable if the strain became too great. This time the departure from Plymouth was made without ceremony. It was decided that the ships should proceed to mid-ocean, splice the cable, and lay it down in opposite directions.

On the way out the fleet encountered a terrific storm. It was so severe and lasted for more than a week that, day after day, it seemed as if nothing could save the *Agamemnon* and her precious cargo from being sent to the bottom. At length the

fury of the gale spent itself, and the ships met in safety at the appointed spot. The cable was spliced and the machinery began to pay it out. When scarcely three miles had been laid the cable parted. The ships returned, respliced the cable and made a new start. But at a distance of fifty miles, without warning, the cable again broke. For the third time the gallant ships re-

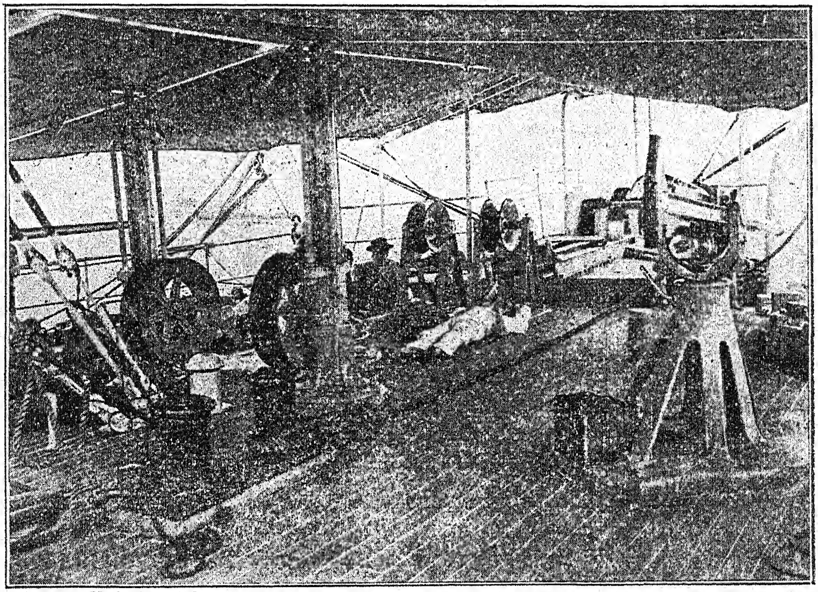


AN OLD PRINT ILLUSTRATING THE ARRIVAL OF THE *GREAT EASTERN*, CARRYING THE ATLANTIC CABLE, IN NEWFOUNDLAND, JULY 27, 1866.

turned to the rendezvous, and another splice was made. They proceeded very carefully. About 200 miles of cable had been laid. Optimism was running high. Every member of the enterprise felt that, at last, success would crown their efforts. Then, without apparent cause, the cable snapped twenty feet behind the *Agamemnon*.

Many of the stockholders were now in favor of abandoning the project; but the counsel of Field and Thomson prevailed, and it was decided to make a third attempt immediately. It was destined to succeed. Although the precious cable was threatened by icebergs and, in one instance, by a whale which

grazed it in passing, the *Niagara* landed her end in Trinity Bay, Newfoundland, August 5, 1858, and on the same day the *Agamemnon* landed hers in Valentia Harbor. All through, telegraph communication had been maintained from ship to ship, and now for the first time in history messages were cabled from coast to coast. Queen Victoria and President Buchanan exchanged



Courtesy U. S. Signal Corps.

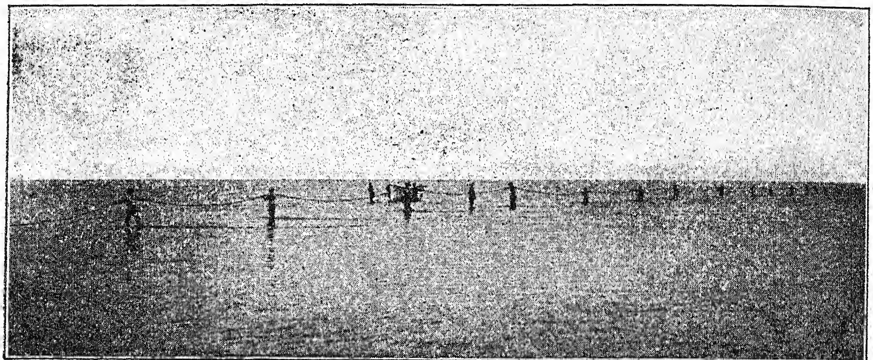
FORWARD CABLE MACHINERY, U. S. CABLE SHIP *BURNSIDE.*

greetings. On either ocean side the promoters were regarded as heroes, and honors were heaped upon them. But in the midst of these celebrations, when the cable was scarcely a month old, the last message passed over it. Ignorance on the part of the electrician in charge of the electrical requirements of cable transmission resulted in the use of too high voltages, and the insulation had been ruined.

The Great Eastern is Chartered for Cable Work

Undaunted, Field still persisted. However, with the Civil War approaching at home, and the numerous disasters fresh in the public mind, he took no part in the project for a number of

years. In 1865, however, he organized another company, the necessary capital again being mostly raised in England, and chartered the famous *Great Eastern*, a mammoth ship too large for the commerce of that day. The expedition sailed from Valentia Bay in July of that year, and succeeded without mishap in covering nearly two-thirds of the distance, when the *Great Eastern's* machinery broke down. As she was tossed by the



Courtesy U. S. Signal Corps.

LANDING SHORE END OF CABLE FROM *BURNSIDE*, PHILIPPINE ISLANDS.

waves, the cable parted and was lost. Surely fate seemed against the undertaking.

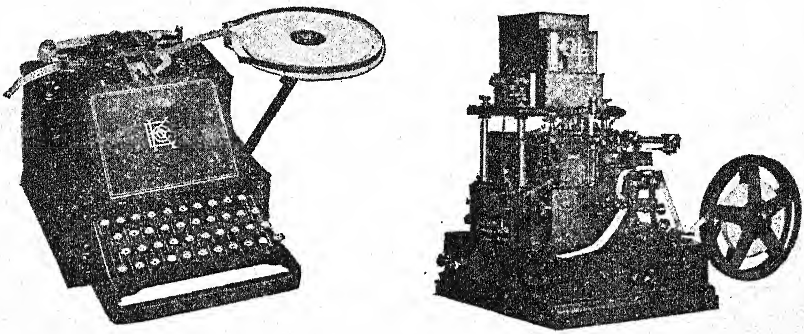
A man of less steadfast faith and courage would have given up. But Field's purpose was unshakable. A new company was organized and on July 13, 1866, the *Great Eastern* started on her second venture. This time it was crowned with success, and in just two weeks the cable was safely landed on the Newfoundland shore. From that day to this the world has never been without transatlantic cable service. With little delay the *Great Eastern* sailed back to recover the lost cable of the previous year. After hooking the cable twenty-nine times, and as often losing it, the thirtieth effort brought it to the surface. It was spliced with new cable and carried in safety to the cable station at Heart's Content, Newfoundland.

Cyrus W. Field, after years of diasppointment, had finally succeeded. It was an achievement worthy of monumental

honors. Thanks to his patient determination, submarine cables now bind together in friendly intercourse the Old World and the New.

Instruments Used in Submarine Cabling

The mechanics of submarine telegraphy are much more complicated than are those on land. A long cable has its metallic core, insulating sheath, and the salt water outside acts like a huge Leyden jar or condenser. The current flowing in the core induces, in the water, opposing currents which enormously



(Left) KEYBOARD PERFORATOR OF A CABLE OFFICE.
(Right) SIPHON RECORDER THAT RECEIVES THE MESSAGE.

retard the speed of transmission. Furthermore, the currents are very weak. This is necessary because of the great resistance of such a long conductor, and the fact that only comparatively small voltages—not over eighty volts—can be used. In one sense the success of submarine telegraphy really depended upon the ability to devise an instrument delicate enough to detect these feeble currents. It was accomplished by Sir William Thomson's mirror galvanometer.

This instrument is essentially the same as our very sensitive spot-light galvanometers of to-day. The current from the cable was passed through a coil of many turns of fine, silk-covered wire. In the heart of the coil in a little air-chamber, suspended by a delicate fibre of silk floss, was a small round mirror. On the back of the mirror were four tiny magnets. The magnetic

field from the currents in the coil caused the tiny magnets to turn the mirror one way or the other, depending upon the direction of the current. Upon the mirror was focussed a beam of light which, in turn, was reflected to a white screen. As the mirror rotated with the changing cable currents, this beam of light moved back and forth on the screen tracing out the dots and dashes of the code. In cable transmission, positive and negative currents are alternately sent to the line; that is, the cable current is constantly reversed. A deflection in one direction means a dot and in the other a dash.

So delicate a recording instrument is the mirror galvanometer that the feeblest currents will operate it. When the first two Atlantic cables had been successfully laid they were connected together at Newfoundland and the current from a tiny cell, consisting of a lady's silver thimble, a bit of zinc, and a few drops of sulphuric acid, sent through them. Even the signals from this infinitesimal current traversed the ocean twice, and were successfully received by the mirror galvanometer.

But, though this was a remarkable invention, it did not record the message. Again Sir William Thomson was equal to the emergency and met it with the siphon recorder. The feeble cable currents would not operate heavy sounders nor any of the printing devices used on land lines. Whatever was to be the recording device, it must require but very slight energy to set it in motion. Just as its name indicates, in this second invention Sir William Thomson used a real ink-carrying siphon to record the message. The cable currents passed through a coil of very fine wire, delicately suspended between the poles of a strong permanent steel magnet. By means of slender filaments the motion of this coil was communicated to the long arm of a fine glass siphon. The short arm of the siphon dipped into a reservoir of ink and the other end glided back and forth across a strip of moving tape. Thus, as the currents corresponding to the dots and dashes deflected the coil first in one direction and then the other, the record was written on the tape in a characteristic wavy line.

Cables are the arteries of international communication. Seventeen of them pass beneath the Atlantic. Two cross the Pacific. They thread the Mediterranean and the Red Sea to

India and the Far East. They creep beneath the arms of the seven seas, and skirt the continents. In all, this small planet boasts, approximately, 1,800 government and privately owned submarine cables, measuring nearly a quarter of a million nautical miles. Over them pass 40,000 cablegrams a day. They bring the remote regions of the earth into contact with the great centres of life and commerce.

CHAPTER IV

TALKING OVER A WIRE. THE STORY OF THE TELEPHONE

ON the afternoon of June 2, 1875, in the hot stuffy attic of Charles Williams' electrical shop at 109 Court Street, Boston, a man and an apprentice lad were hard at work over a balky piece of electrical mechanism. For many weeks the two had been engaged on the invention of a telegraph by which they hoped to be able to send a number of messages over a single wire at the same time. But it was something more than this; it was to be a "harmonic" telegraph which would send, not click-like signals, but musical notes. Despite every effort, the device stubbornly refused to operate as its inventor had long hoped and steadfastly believed it would. And yet on this memorable afternoon, without knowing it, they were about to make history. A new instrument was to take its place in human affairs. Inventive genius was to be rewarded in the birth of the telephone.

The man was Alexander Graham Bell, a young Scotsman who had come to Canada in 1870 to seek health and fortune in a new land. In 1872 he moved to Boston, and continued his experiments with sound-transmission. His assistant was Thomas A. Watson, an employee in the electrical shop of Charles Williams. As described by Watson, Bell was at this time "a tall, slender, quick-motioned man with pale face, black side-whiskers and drooping mustache, big nose, and high sloping forehead crowned with bushy, jet-black hair." For generations his ancestors had been interested in human speech. Bell himself was a master of the science of sound and an elocutionist of some note. While a mere lad he and his brother Melville had invented a talking device that gave a very good imitation of the word "mam-ma." Melville made the lungs and vocal cords and Graham the mouth and tongue.

Adopting the profession of his family, Bell became a teacher of deaf-mutes. He taught a system of "visible speech" (teach-

ing speech by lip-movement), invented by his father. After completing his education he went to London where he made the acquaintance of Sir Charles Wheatstone, the inventor of the English telegraph. On this occasion he learned that the German physicist Helmholtz had vibrated tuning-forks by means of electromagnets. Fascinated, as he always was with anything relating to sound, this fact deeply impressed Bell. If an electric current could be made to vibrate a tuning-fork, why should not a vibrating reed or fork be made to vary an electric current so as to reproduce sound? Reasoning in this way, Bell conceived the idea of a musical telegraph. Why should it not be possible to send as many messages over a single wire as there are notes on a piano? This was the idea with which Bell started, and from it developed the telephone.

Shortly after coming to America Bell was engaged by the Board of Education of Boston to introduce his system of visible speech in a school for deaf-mutes that had just been established in that city. His work met with great success, and he was soon appointed to a professorship in Boston University. Later he established a school of his own and, absorbed in his professional work, he had little time to think of a musical telegraph. Still the idea persisted.

How Bell's Two Pupils Helped Him

About this time there came into Bell's life two young people destined to have a profound effect upon his future career. He received as a private pupil a little deaf-mute, Georgie Sanders, who lived with his grandmother in Salem. As part payment for his services Bell went to live in the Sanders' home, where he was allowed to have a workshop in the basement. He also made a warm friend of the boy's father, Thomas Sanders, without whose sympathy and financial assistance the invention of the telephone would have been impossible. There also came to him at this time another private pupil, Mabel Hubbard, a girl of fifteen who had lost her hearing in infancy. Not only did she take the keenest interest in his electrical experiments, but four years later she became his wife, and her father, Gardiner G. Hubbard, a prominent lawyer of Boston, did more than any other one man to make a commercial success of the telephone.

Gradually the idea of a musical telegraph thrust every other thought from Bell's mind. He abandoned his school. Only two pupils remained, Georgie Sanders and Mabel Hubbard. Their fathers financed his work, for they had faith in Bell and believed that his idea would bring fame to him and wealth to them all. A new era would be inaugurated in the art of communication.

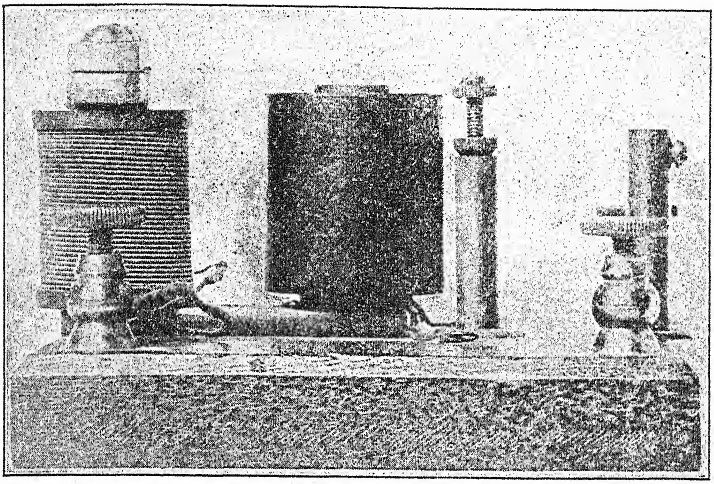
In his laboratory at Salem, Bell worked incessantly. Sleep was a secondary consideration. Sanders says: "Bell would often awaken me in the middle of the night, his black eyes blazing with excitement. Leaving me to go down to the cellar, he would rush wildly to the barn and begin to send me signals along his experimental wires. If I noticed any improvement in his apparatus he would be delighted. He would leap and whirl around in one of his 'war dances,' and then go contentedly to bed. But if the experiment was a failure he would go back to his work-bench to try some different plan."

Slowly there dawned upon Bell's mind a still larger idea. "If I can make a deaf-mute talk," he said, "I can make iron talk." At first only a dream, this idea of sending the spoken word itself over an electrified wire grew into a deep conviction. His interest in a musical telegraph began to vanish. With an enthusiasm scarcely ever equalled, Bell set himself to the invention of an actual talking telegraph. But Sanders and Hubbard had no faith in his new project, and refused further assistance unless he should devote at least a part of his time to the musical telegraph. Therefore he divided his time between the two inventions, working faithfully for a portion of each day upon his original idea. But his heart was in the telephone.

Bell's Experiments with a Dead Man's Ear

At the same time Bell had been trying to improve his system of visible speech. In these experiments he used a speaking-trumpet as transmitter, and a harp as receiver. In this way he discovered that he could make sound waves plainly visible by speaking against a drum or membrane to which he had attached a short pointer, or stylus. Doctor Clarence J. Blake of Boston suggested the use of a human ear, and provided for Bell's use

one that he had taken from a corpse. Bell then constructed an apparatus, of which the dead ear formed a part, and which made it possible for the spoken voice to trace a record of its vibrations in beautiful curves on smoked glass. In the gray light of his basement laboratory Bell must have presented a



BELL'S "HARMONIC TELEGRAPH."

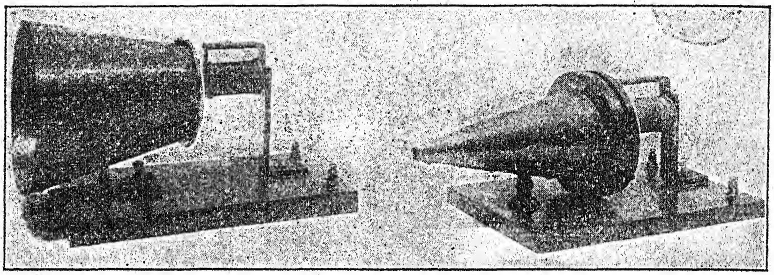
It was with this instrument that Alexander Graham Bell began the series of experiments which finally culminated in the invention of the telephone. Instead of sending signals over a wire, which would be received as intelligible clicks, Bell conceived the idea of sending musical notes which could be identified by their pitch. Clock-spring reeds were vibrated electromagnetically, very much like the clappers of house-bells. One day a clock-spring became attached to its magnet, with the result that a feeble sound was heard at the receiving end, the current flowing continuously through the line. By accident the fundamental principle of the telephone was thus discovered.

diabolical appearance as he shouted into this dead man's ear. The inhabitants of Salem might well have thought that the witches of old had come back to disturb once more their peaceful town. Here was a delicate ear-drum which, in response to the sound waves of the human voice, set into vibration the heavy bones behind it. "Why," he asked himself, "should not a vibrating iron disk set an iron rod or an electrified wire into vibration?" How this was to be accomplished, he did not know, but he felt he was moving in the right direction.

Just at this point, while on a visit to Washington, Bell met

the venerable Joseph Henry, who for a generation had been the pioneer of electrical science in America. From Henry, Bell received the utmost encouragement. Replying to Bell's statement that he did not possess sufficient electrical knowledge to perfect the telephone, Henry said: "Get it." This was just the spur that Bell needed. He returned to his workshop with a mighty determination to succeed.

Like Morse, of telegraph fame, Bell's early days were beset with poverty. His professional income had practically van-



BELL'S ORIGINAL INSTRUMENTS NOW PRESERVED IN THE NATIONAL MUSEUM, WASHINGTON.

The transmitter and receiver were of substantially similar construction. About one pole of a permanent bar magnet was wound a coil of fine copper wire. In front of the pole was mounted a soft-iron disk, to which the mouthpiece was attached. The sound waves of the voice, striking the sending disk, made it vibrate. This vibration caused the line current to vary. The disk of the receiving instrument vibrated in sympathy with these electrical variations in the line.

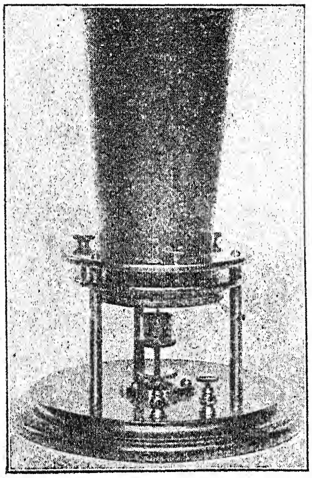
ished. His two remaining pupils barely supplied him with the necessities of life. Sanders and Hubbard provided funds for his experimental work only. Writing to his mother at this time, he says:

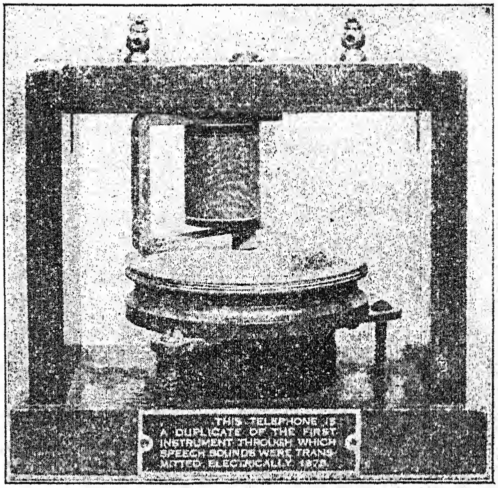
"I am now beginning to realize the cares and anxieties of being an inventor. I have had to put off all pupils and classes, for flesh and blood could not stand much longer such a strain as I have had upon me."

This was in 1874. Bell was now established in the attic of Williams' electrical shop in Boston. Sanders and Hubbard were paying his assistant, Thomas A. Watson, nine dollars a week, and the inventors were dividing their time between the musical telegraph and the telephone.

The Telephone is Invented

We now come to the memorable afternoon with which we began this chapter. Alexander Graham Bell's telegraph comprised, among other things, clock-spring reeds which were vibrated by electromagnets, very much like the clappers of elec-





(Left) THE FIRST TELEPHONE THAT TALKED.

This is the transmitter used by Bell when on March 10, 1876, he telephoned to his assistant: "Watson, please come here, I want you."

(Right) BELL'S EXPERIMENTAL TELEPHONE (1875).

After having discovered the principle of the telephone accidentally with the aid of his "harmonic" telegraph, Bell instructed his assistant, Watson, to build this instrument. The armature of the electromagnet had the form of a hinged iron lever, carrying a stud at one end, which pressed against the centre of a stretched membrane of goldbeater's skin. Speech sounds were actually transmitted with this instrument in 1875, but it served chiefly the purpose of revealing the feasibility of the plan.

tric house-bells. Watson was sending, and Bell receiving. As Watson pressed down the key at his end, to make the clock-spring at the sending end of the wire vibrate, the contact points fused together. As a result, the clock-spring was simply held down by its electromagnet, just as an ordinary horseshoe magnet attracts and holds a needle. Watson tried to pluck the spring free. This made it vibrate over the electromagnet. Bell, with

blazing eyes and alive with excitement, came rushing into the room. A feeble sound had at last passed over the wire, and his keen ear had caught it. "What did you do then?" he demanded of Watson. "Don't change anything. Let me see."

The first faint cry of the baby telephone had passed into history. In that moment a new epoch in the art of communication was ushered in. The fundamental principle of the modern telephone was operating in that simple apparatus. By accident the current was flowing continuously through the electromagnets and the line. The plucking of the spring had varied the intensity of this current and thrown into vibration the corresponding clock-spring at the receiving end of the line.

The discovery, one of the greatest in all history, had been made. The rest was a mere matter of detail and mechanical perfection. It seems easy now. But the inventors worked for forty long weeks before they made their telephone talk. The very afternoon of the discovery Bell gave Watson directions for making the first telephone. Watson says: "I was to mount a small drumhead of gold-beater's skin over one of the receivers, join the centre of the drumhead to the free end of the receiver-spring, and arrange a mouthpiece over the drumhead to talk into. I made every part of that first telephone myself, but I didn't realize while I was working on it what a tremendously important piece of work I was doing."

Forty weeks of patient experimentation and then, on March 10, 1876, Watson heard distinctly through the telephone-receiver this message: "Mr. Watson, please come here, I want you." It was a message that proved to be as immortal as Morse's: "What hath God wrought?"

Progress now became rapid and certain. Watson says: "The telephone was soon talking so well that one didn't have to ask the other man to say it over again more than three or four times before one could understand quite well, if the sentences were simple."

The fates were kind to Bell. The stage had already been set for the coming of his invention. The Centennial Exposition was just opening in Philadelphia, and this afforded precisely the opportunity that he needed. Bell had not expected to attend the exposition himself. Overcome at the grief of his fiancée,

when at the railroad station she learned that he would not accompany her, Bell rushed madly after the moving train and climbed aboard.

Hubbard had secured for Bell a small table in an out-of-the way corner of the Education Building for the exhibition of his apparatus. No one visited him. No one was interested in his invention. It was only a "toy." What if speech could be sent over a wire? Of what value could that be? No one had the vision to see the tremendous possibilities hidden within this crude piece of mechanism. But Bell patiently awaited the judges' tour of inspection. At last they came. It was just at dusk. Tired and hungry after a long day of continuous inspection, they were in no mood to waste time over a useless plaything. One or two approached the table, picked up the instrument, fingered it listlessly. As the judges were about to pass on, there was enacted a scene worthy of the brush and genius of a master artist. Dom Pedro, the young emperor of Brazil, followed by a company of gaily attired attendants appeared, and, rushing up to Bell, greeted him with great fervor. Dom Pedro had visited Bell's school for deaf-mutes years before and had been pleased by his system of visible speech. He was intensely interested in the new invention. Walking to the other end of the line, Dom Pedro placed the receiver to his ear. Bell spoke and the emperor dropped the instrument, exclaiming: "My God, it talks."

There in the twilight stood the judges, awed and silent witnesses of this picturesque but momentous event. One by one they came forward, utterly forgetful of weariness and hunger, each in his turn eager to test this latest marvel of science and invention. There were Joseph Henry and Sir William Thomson, the latter declaring it to be "the most wonderful thing he had seen in America." From that moment Bell's telephone became the most popular exhibit of the exposition, and overnight its inventor leaped to world fame.

Bell's original telephone was exceedingly simple. About one pole of a permanent bar magnet was wound a coil of fine copper wire. One end of the wire was grounded, while the other went to the line. In front of the pole was mounted a soft iron disk to which was attached the mouthpiece. The receiver was of identical construction. The sound waves of the voice, striking

upon the sending disk, made it vibrate. This vibration caused the current in the line to vary. The disk of the receiving instrument was vibrated in sympathy with these electrical variations in the line. Hence the receiving disk vibrated exactly as the sending disk vibrated when words were spoken against it. The receiving disk therefore talked. In other words, Bell first changed sound into electrical current, and then changed the current back again into sound. The same instrument served both for transmitter and receiver. But simple as these instruments were, they worked on the same principle as those of to-day.

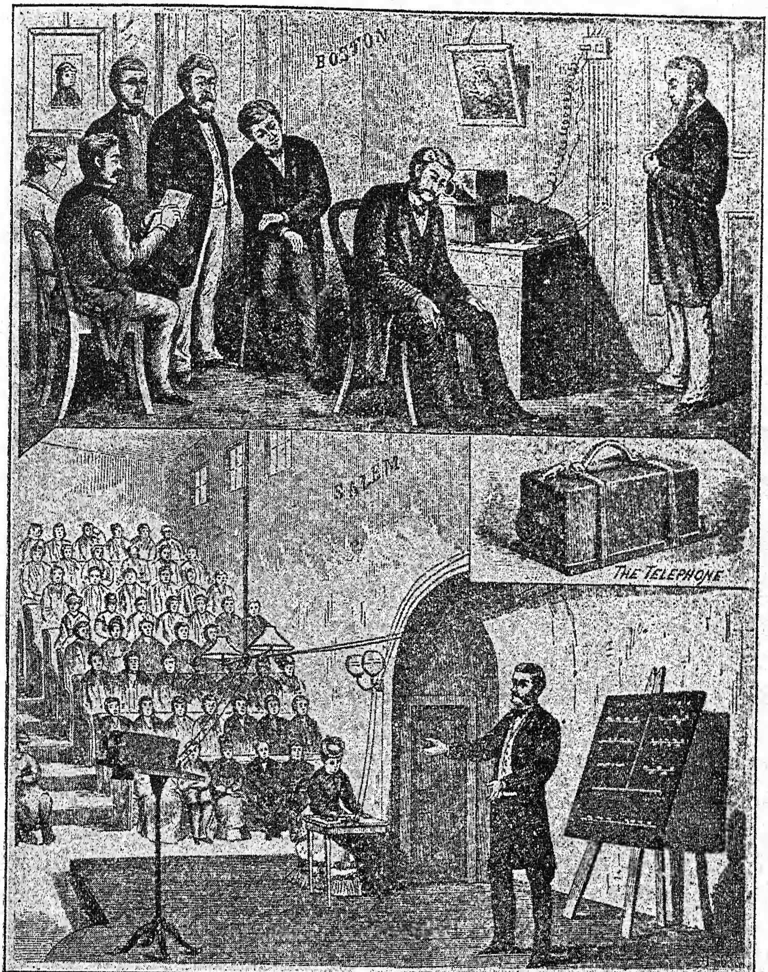
Introducing the Telephone to the Public

Although the telephone had taken rank as among the most wonderful bits of mechanism ever produced, the interest in it was still only that of curiosity. No one could see any possible use for it. Its inventor had won fame, not fortune. The public, remaining sceptical, had to be educated. To this task of winning popular favor Gardiner G. Hubbard immediately devoted himself. With an enthusiasm and a breadth of vision rarely equalled elsewhere in the history of invention, he became the apostle of the telephone.

Hubbard's first step was to arrange a series of ten lectures to be given by Bell and Watson. The first demonstration was given before the Essex Institute of Salem. Having no lines of their own they obtained permission to use a telegraph line for the occasion. Bell gave the lecture while Watson, located in the Boston laboratory, provided the entertainment. At the request of Bell, Watson played various musical instruments, and although not a singer, he was required to render such favorite songs as "Auld Lang Syne" and "Do Not Trust Him, Gentle Lady." The audience was delighted. Newspaper editors featured the performance. Invitations to repeat the lecture came like a flood. And yet the interest was chiefly that of curiosity. Still these lectures did bear fruit. They acquainted the public with the uses and purposes of the telephone, and on the small admission returns Bell was able to marry and to sail for Europe on his wedding trip.

On the occasion of one of these lectures Watson invented

the first telephone-booth. In order to make his audiences hear, he was compelled to shout into the mouthpiece of the



By courtesy of Munn & Company. From the Scientific American of March 31, 1877.

INTRODUCING THE TELEPHONE TO THE PUBLIC.

The public had to be taught the principle and function of the telephone. Hence Gardner Hubbard, Bell's father-in-law, arranged a series of lectures to be given by Bell and Watson. The first demonstration was given before the Essex Institute of Salem, in 1877. Watson, in Boston, played musical instruments and sang. The audience was delighted.

transmitter. This annoyed his landlady, and strained relations had already arisen between them. Knowing that on the Boston-New York trial he would be required to use an extraor-

dinary amount of lung power, Watson removed the blankets from his bed and arranged them in a sort of loose tunnel. In this soundproof booth he was able to shout as loudly as he pleased without fear of being heard.

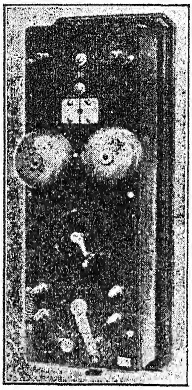
The Bell Company and the Western Union

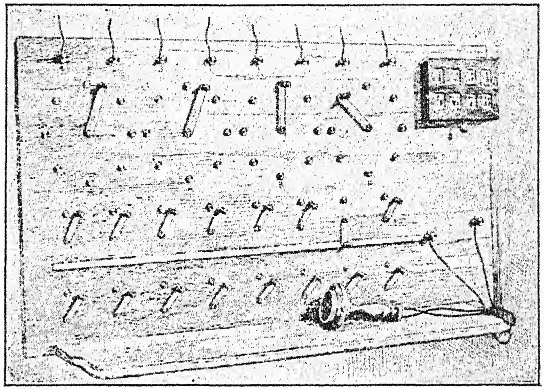
While Bell was in Europe Hubbard organized the "Bell Telephone Association," with Bell, Hubbard, Sanders, and Watson as partners. The first out-of-doors telephone-line to be established was between the Williams' electrical shop in Boston and Mr. Williams' home in Somerville. Then the unexpected happened. A man from Charlestown, named Emery, came into Hubbard's office one afternoon in May, 1877, and laid down twenty dollars for the lease of two telephones. It was the first money ever received for a commercial telephone. In the promise it gave of future rewards it seemed like a million dollars. In that same month, too, the first crude exchange was established in Boston. Six telephones were loaned to Mr. Holmes, the proprietor of a burglar-alarm system, who installed them in six banks and connected them to a central station. Very soon exchanges were established in New York, New Haven, Bridgeport and Philadelphia. By August, 778 telephones were in use. The demand for them was so great that they could not be supplied. They were also expensive to manufacture, and, despite the appearance of prosperity, the company was on the verge of financial ruin. The only member of the company who had money was Sanders, and his fortune was not large.

Not realizing the value of his invention Bell had already offered it to the powerful Western Union Telegraph Company for $100,000. But the "scientific toy" was rejected. The Western Union never dreamed that its monopoly of wire communication could be shaken until several of its New York patrons removed the printing telegraph-machines from their offices and replaced them with telephones. Alarmed at this invasion of their private domain, the Western Union sat up and took notice. They at once organized the "American Speaking-Telephone Company," with a capital of $300,000, and enlisted the services of Gray, Edison, and Dolbear as electrical experts and inventors.

Bell's Rival Claimants

On March 7, 1876, Bell had been granted a patent on his invention. This has been described as "the most valuable single patent ever issued." It is a remarkable fact that *on the*

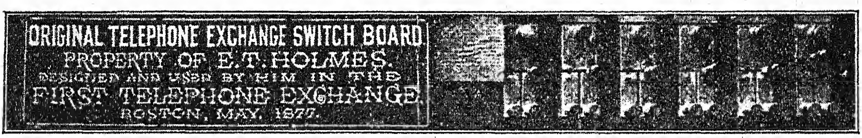




(Left) THE FIRST MAGNETO CALL.

The original method of calling a subscriber was by thumping on the transmitter diaphragm with the butt end of a lead-pencil. Then Watson devised a special kind of "thumper," which was operated by turning a button on the outside of the telephone-box. He followed this with the magneto-electric call-bell, still widely used on country lines, and of which this is the first model.

(Right) EARLY "CENTRAL" SWITCHBOARDS.



THE FIRST TELEPHONE SWITCHBOARD.

E. T. Holmes, of Boston, proprietor of a burglar-alarm system, had six telephones installed in six banks, and connected with a central station. This was in 1877. Hence the first "central" was a switchboard by day and a burglar alarm by night.

same day that Bell filed his application for a patent, Elisha Gray filed a claim for a similar one. Gray had risen from a blacksmith's apprentice to a professorship in Oberlin College. He had invented a musical telegraph that really worked, and later he claimed to be the rightful inventor of the telephone. The Western Union, seizing upon these claims, began suit

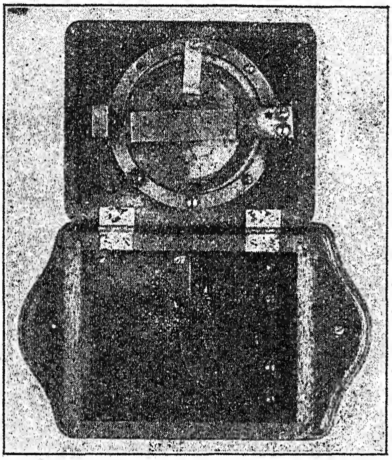
against the Bell Company to establish the rights of Gray. Although beset with poverty, the little group of telephone pioneers fought the attack with the help of the ablest lawyers of Boston. It was conclusively demonstrated that Bell was the rightful inventor of the telephone. The Western Union officers made peace and surrendered to Bell a monopoly of the telephone field, retaining for themselves similar privileges in the domain of telegraphy.

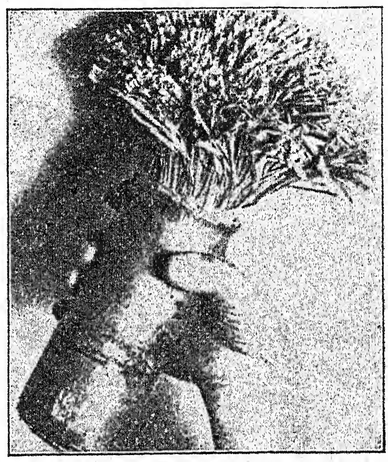
The result was magical. The Bell stock shot up to $1,000 a share. At this point the original promoters sold out their interests, each receiving a comfortable fortune, and turned the development of the business over to other men.

But rival claimants did not cease their fight. Back in 1861 Philip Reis, the son of a poor baker in Frankfurt, Germany, had invented an electrical contrivance that would carry a tune but could never be made to talk. It worked upon the principle of a make-and-break telegraph and not on the variation in the intensity of the electric current. Professor Amos E. Dolbear improved this device and claimed to be the original inventor of the telephone. But after a long legal battle the courts decided against him. When produced in court his telephone refused to work, and, in extenuation, one of Dolbear's attorneys vouchsafed: "It can talk, but it won't." In all, Bell and his company were compelled to fight more than 600 lawsuits to maintain their rights. No other patent has ever been more bitterly contested, and no claim to a great invention more clearly proven.

Back in the midnight of financial chaos and legal battle, Edison invented for the Western Union a transmitter that made their instruments vastly superior to those of the Bell Company. The principle consisted in varying the electric current by varying the pressure between two contact points. In 1876 a poor German boy, Emil Berliner, who had come to this country a few years before, became fascinated with the telephone and started out to invent one on entirely new lines. The result was a transmitter identical in principle with that of Edison, invented but two weeks earlier. Since, however, Edison was in the service of the Western Union, Berliner's claims were entirely ignored. But fourteen years later the Supreme Court of the United States declared Berliner to have been the original in-

ventor of the transmitter. Edison, without any knowledge of Berliner's device, greatly improved it by substituting soft carbon in place of steel for the contact points. Professor David E. Hughes of Kentucky invented a carbon microphone which Francis Blake of Boston changed into a practical transmitter. The Blake transmitter was as good as Edison's, and the Bell Company bought it, thus placing them on an equal footing with





(Left) EARLY BLAKE TRANSMITTER.

Professor David E. Hughes invented a carbon microphone which Francis Blake, of Boston, changed into a practical transmitter.

(Right) A TELEPHONE CABLE BOUQUET.

This picture shows a section of a 1,200-pair cable. Such a cable contains 2,400 wires, encased in a leaden sheath less than three inches in diameter.

the Western Union. The idea of using carbon in the form of small granules was that of the Reverend Henry Hunnings, an English clergyman. An expert of the Bell Company named White developed the transmitter into its present form.

After the Western Union had failed in their attack on the Bell patents, public confidence was captured and business grew so rapidly that a general manager became necessary. For this post, Hubbard selected a young man named Theodore N. Vail, the general superintendent of the Railway Mail Service, whose granduncle, Stephen Vail, had built the engines for the first steamship to cross the Atlantic. In executive ability and sheer

genius for organization Theodore Vail has never had a superior. He came to a bankrupt company whose affairs were in utter chaos. But his enthusiasm was unbounded; his faith in the possibilities of the telephone never faltered. In his prophetic vision he saw the future as few men have ever done. In 1879 he said: "I saw that if the telephone could talk one mile to-day, it would be talking a hundred miles to-morrow." Under his direction funds were raised, legal battles fought, agents licensed, exchanges established, and many hundreds of miles of wire strung. It was his dream to make the telephone business a national institution. His employees were infected by his enthusiasm. "It was work without ceasing, days, nights, Sundays, and holidays." Without Theodore N. Vail the Bell Company might have died in infancy.

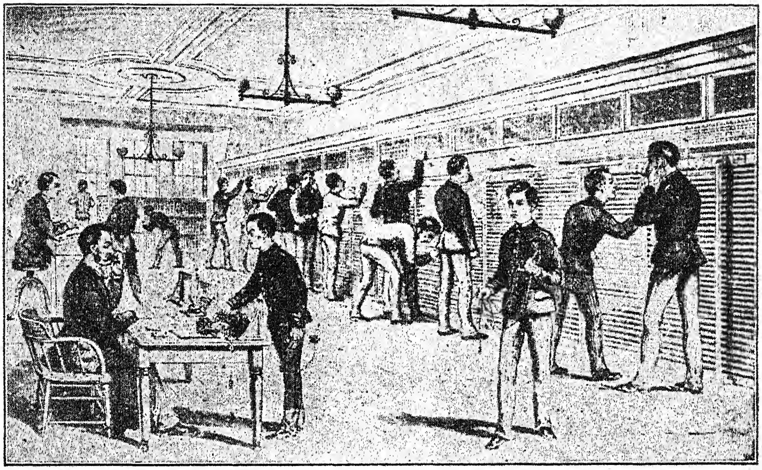
Telephone Apparatus and the Switchboard

When the telephone came into public use one of Watson's first tasks was to devise some sort of signalling mechanism. "It began to dawn on us," he said, "that people engaged in getting their living in the ordinary walks of life couldn't be expected to keep the telephone at their ear all the time waiting for a call, especially as it weighed about ten pounds then and was as big as a small packing-case." The original method of calling a subscriber was by thumping on the transmitter diaphragm with the butt end of a pencil. Then Watson devised a special kind of "thumper" which was operated by turning a button on the outside of the telephone-box. He followed this shortly after with the familiar hand-operated magneto-electric call-bell, still widely used on country lines.

In the early days of telephoning this notice was usually posted at stations: "Don't talk with your ear, nor listen with your mouth." This was the period, too, when all the farmers waiting at a country grocery would rush out and hold their horses when they saw any one preparing to telephone. But the improved transmitter banished the single instrument for both talking and receiving and greatly increased the efficiency of transmission.

The early "centrals" were exceedingly crude. The first telephone switchboards were built on the plan of telegraph-

switchboards. They were good enough for a few lines, but not for thousands. Boys, not girls, were employed as operators, and the service was wretched. The boys ran about like mad and pandemonium reigned. It required half a dozen boys and as many minutes to answer a single call. Impudence was a



BOYS, NOT GIRLS, MANNED THE EARLY CENTRALS.

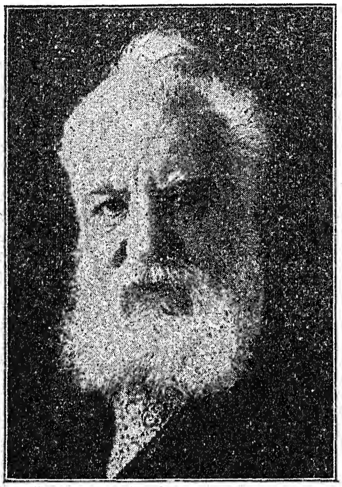
It required about half a dozen boys and as many minutes to answer a signal call. J. J. Carty, now vice-president of the American Telephone & Telegraph Company, was once a switchboard boy. This is a contemporaneous picture of the Cortlandt Exchange, New York, in 1879.

telephone characteristic; there was a never-ceasing babble of noise, and tedious delays were the rule.

Then came a respite. The boys were banished and girls took their places. More important still, Charles E. Scribner, the "wizard of the switchboard," took his place among the ranks of the telephone inventors. Scribner connected himself with the Western Electric Company of Chicago, the largest manufacturers of telephone equipment in the world. To the genius of Scribner more than to any other one man we owe the modern switchboard. In his perfection of it he has taken out more than 1,000 patents. It is one of the most intricate pieces of mechanism known to science. In its completed form one of these distributors of human speech may have as many as 2,000,000 parts.

A Modern Exchange or "Central"

Let us enter a modern "exchange" and see how a Scribner switchboard operates. In any large exchange there are two sets of operators, the "A" and the "B." In a New York city exchange each "A" operator tends about 40 or 50 lines direct from the subscribers, and connects them through trunk lines with the other exchanges of the city. If 5,000 lines enter this



Copyright by Harris & Ewing.

(Left) ALEXANDER GRAHAM BELL.
(Right) C. E. SCRIBNER,
Who has patented more than 900 telephone inventions.

exchange there must be about 100 "A" operators. The "B" operators handle the calls coming to this exchange from the other exchanges of the city. If there are 50 other exchanges, there will be 50 "B" operators besides 1 or 2 to handle calls from the "A" operators of this same exchange.

On the horizontal shelf in front of the "A" operator is a double row of cords, a pair for each subscriber she attends. In front of these is a double row of small electric lamps. One of these lamps is connected with the circuit of the calling subscriber, and the other with that of the subscriber called. In front of the lamps is a row of listening keys; and in front of the keys a

row of buttons for registering on the subscriber's meter every call he makes. At the bottom of the upright panel are the rows of subscribers' "jacks" (contact sockets, connecting with the lines), and under each jack is a tiny electric lamp. Above them is a large number of trunk-line jacks, one set leading to each of the other exchanges of the city. To the immediate left of the operator's position is a group of circuit calling-keys, by which she puts herself temporarily in connection with the "B" operators at the other exchanges of the city.

At each of the "B" panels are jacks for all the subscribers' lines that enter that exchange. In one New York city exchange there are as many as 10,199. If there are 50 "B" operators, each subscriber's line is "fanned out" into as many branches, one for each operator. Then, to one "B" panel come all of the trunk lines from some other one exchange of the city, these lines ending in a row of cords on the horizontal shelf. To the next panel come all the trunk lines from some other exchange, and so on. In front of the row of cords at each position is a row of small electric lamps.

You lift your receiver from the hook, and immediately a signal lamp lights. The operator answers when she sees the light. Suppose your exchange is Cortlandt, and you are calling Spring 1709. Immediately the "A" operator who answers your call presses the Spring Exchange button at her left, and gives the "B" operator there the number wanted, whereupon the "B" operator makes the connection desired. After either of the subscribers hangs up his receiver, the signal lamp in front of the "A" operator corresponding to his cord will light. When both of the lamps light she knows that the conversation is ended, and removes both cords from their jacks. This lights the signal lamp before the "B" operator in the Spring Exchange, and she removes the trunk line cord from its jack. The lines are now free for another call.

If a subscriber is not answered by central at once, the moving up and down of the receiver-hook flashes the signal lamp, calling the operator's attention. This may be done by either party.

The Automatic Girlless "Central"

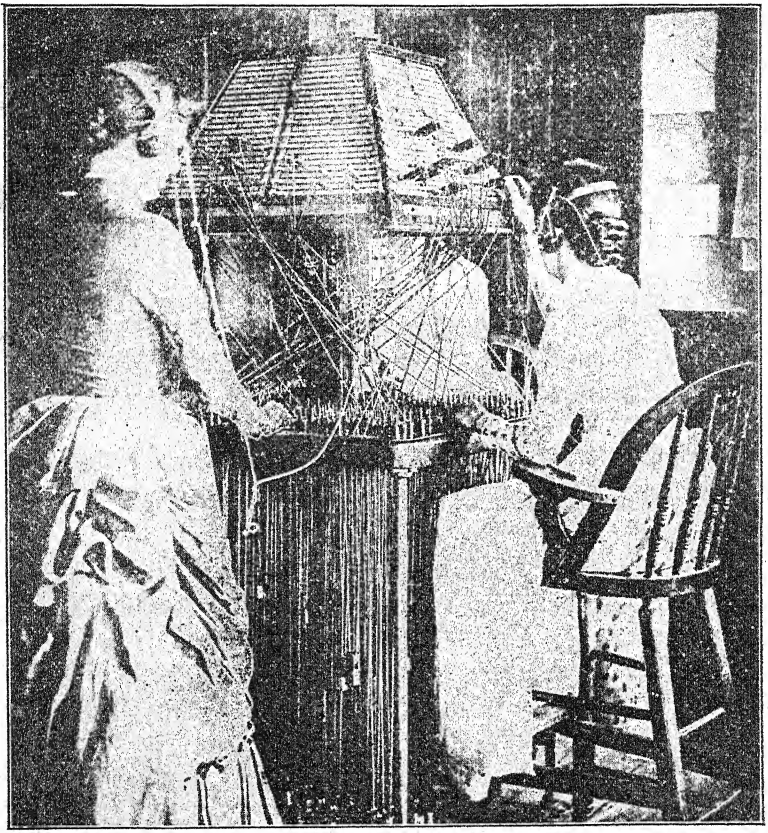
A little more than thirty years ago there lived in Kansas City, Mo., an undertaker named Almon B. Strowger. Strowger got the idea that the switchboard operator of his local exchange was in conspiracy with one of his competitors to ruin his business by falsely reporting his line "busy." The only remedy for such a difficulty, he concluded, was a "girlless" exchange. Therefore he began spending his odd moments in devising such a switchboard. A few days later Joseph Harris, a travelling man from Chicago, came into Strowger's office. Strowger told Harris of his idea and showed him a "foolish contraption" made from a collar-box, some pins, and a lead pencil. Harris was immediately interested. Later he said, "Others laughed at the 'crazy' undertaker, but his fool contraption didn't seem funny to me."

Strowger moved to Chicago, where, in 1891, together with Harris and a number of others, he formed a company called the "Strowger Automatic Telephone Exchange." Fortunately they interested in their enterprise Mr. A. E. Keith, a young electrical engineer from the Brush Electrical Company of Baltimore. To the genius of Mr. Keith is due the modern automatic "central," or machine-switching exchange.

To tell the story of the early struggles of this company would require a volume. We may simply say that intelligent effort and indomitable perseverance have won the day. The factory of the company in Chicago employs 3,000 workers, and covers ten acres of floor space. Their system covers the earth. Dozens of cities in this and other countries have used machine-switching exchanges for more than twenty years. Already New York city has begun to convert her system to the automatic basis, and in a few years' time the "hello" girl will be only a memory.

How does the automatic exchange work? The engineer in charge of the installation work in one of our largest cities told the author he had studied the system night and day for three weeks, before he felt that he understood it. Indeed, to see the bewildering maze of lines, switches, and relays, and then watch their automatic operation, one is staggered by the revelation of such human ingenuity and mechanical perfection.

The subscriber's instrument differs from the usual one only in having at its base a calling device known as a "dial." The small finger-holes of the dial contain the digits from 1 to 9 and 0; sometimes, they also contain letters. Lifting the receiver



RICHMOND (VA.) SWITCHBOARD OF 1882.

Boys were soon banished from the central switchboards and girls took their places. The switchboards were improved, so that connections could be more easily made.

from the hook causes the "line switch" to connect the calling line to a device known as a "selector" and to send back the "dial tone" which corresponds to "number, please?" Now, instead of giving the number in the usual way, the subscriber "dials" it. He puts his finger in the hole of the dial corre-

sponding to the first digit of the desired number, brings it around to the stop, releases it, and repeates the operation with each of the other digits. Dialling the first digit causes the "first selector" to pick out an idle "second selector" in the proper thousand group. The second digit causes this switch to select the particular hundred group wanted. The third and fourth digits control the "connector switch" which joins the calling line to that of the called subscriber. At the same time it sends the ringing current over the called line. If the line is busy, automatically the "busy tone" comes back to the person calling. Placing the receiver on the hook, when the conversation is complete, instantly breaks the connection and clears the apparatus for another call.

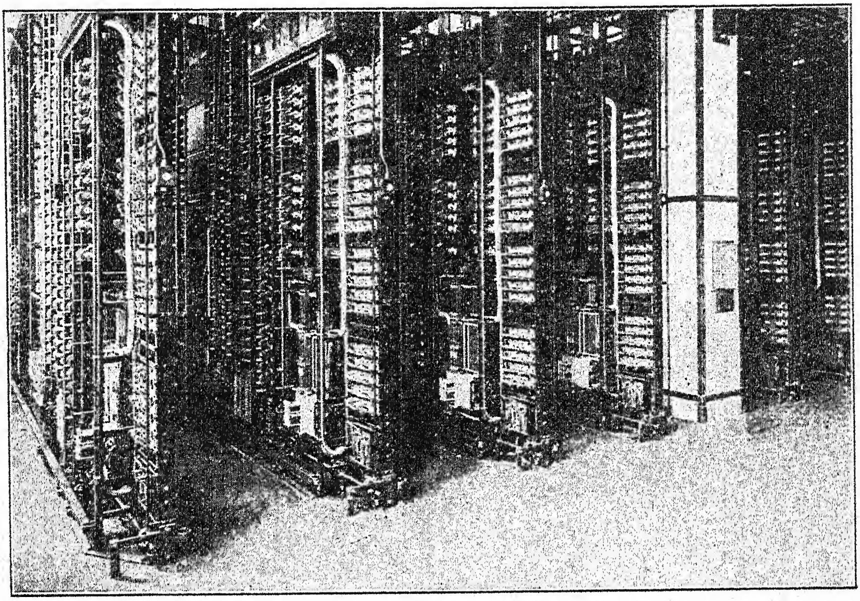
So completely has the mechanism been developed that both hand and automatic systems may be used in the same city at the same time. Every detail has been perfected: coin-boxes, toll-calls, long-distance, and "information." But in handling long-distance and toll-calls, and for certain other services, the assistance of operators is still required to a limited extent.

The cost of installation is greater for the automatic than for the "girl" exchange, but, once installed, its operation is more economical. The automatic system insures greater speed, absolute secrecy, and it is always "on the job." It never sleeps, never has special hours, never grows weary. It represents one of the greatest triumphs of telephone engineering, and its universal adoption is bound to come in the near future.

General John J. Carty's Inventions

In 1880 a nineteen-year-old lad entered the employ of Thomas Hall at 19 Bromfield Street, Cambridge, Mass. Thomas Hall kept an electrical shop and the lad was John J. Carty, now vice-president of the American Telephone and Telegraph Company. He has been identified with the principal achievements in developing the art of telephone communication in this country. He has largely created the profession of telephone engineering. Only the other day, as we shall presently see, he startled the world with the greatest triumph in the art of communication that has ever been known.

Of that early experience in Hall's electrical shop, Carty says: "I swept out the place, cleaned about there, did errands, mixed battery solutions, and got a great deal of experience in one way or another." As the result of a prank that he and the other boys of the shop played on the boss, Carty was "fired." His



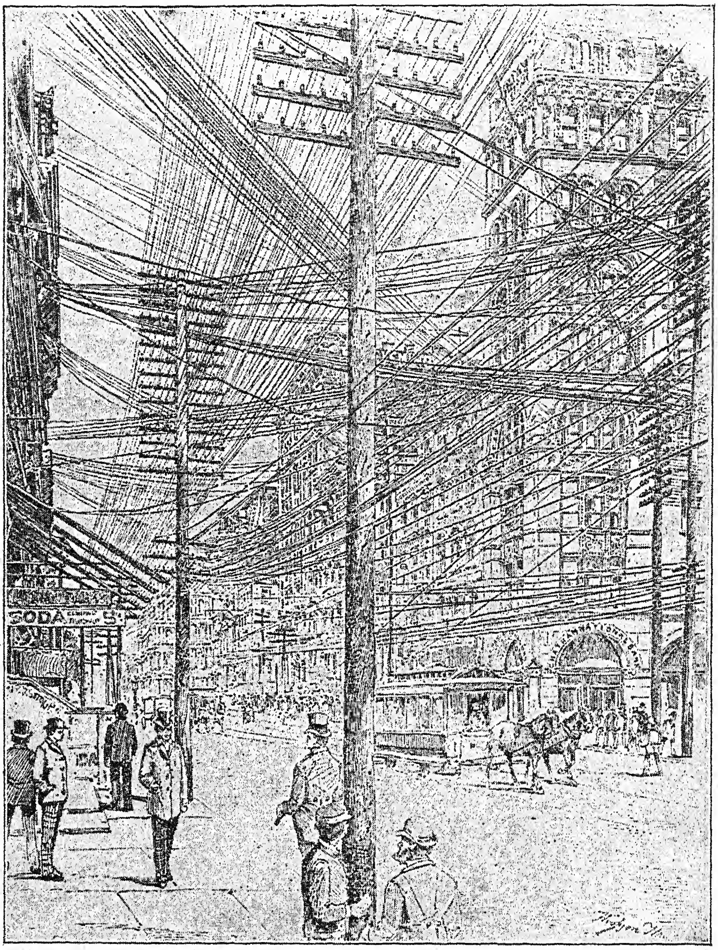
BEHIND THE SCENES IN A GIRLLESS CENTRAL.

Girls are giving place to machines in telephone exchanges. The subscriber operates a dial on his telephone and the automatic machines make the connection. This is one of the automatic centrals developed by the American Telephone and Telegraph Company along lines originally laid down by Strowger.

next job was as "hello boy" in a telephone exchange in Boston. "The little switchboards of that day," he says, "were a good deal like the automobiles of some years ago—one was likely to spend more time under the switchboard than sitting at it. In that way I learned a great deal about the arrangement and construction of switchboards." Eventually Carty got in touch with Scribner, and as a result of this and his own later experience became expert in the construction and installation of switchboards. Later he was placed in charge of the switchboard department of the Western Electric Company.

His first great triumph was to overcome the babble of weird

underground noises that day and night played over the telephone circuits. He did this by substituting a return wire in



BROADWAY AND JOHN STREET, NEW YORK, IN 1890.

As the use of the telephone grew the streets of cities were threaded with a maze of telephone wires. This is a view of Broadway and John Street in 1890. The danger of these overhead wires was such, and the interruption to telephone traffic in storms so intolerable, that the telephone company laid its wires in conduits underground.

place of the earth, which had been used to complete the circuit in all of the early lines. The result was magical. The tantalizing interruptions disappeared, and quiet has since reigned.

Vail then brought Carty to New York and assigned him the task of putting the maze of overhead wires in underground cables. This he did in record time and at half the former cost, devising in the process cheaper and better cables. For the individual batteries along the line, he substituted the central battery system. The "bridging bell" by which several subscribers may be put on a single line without their signalling apparatus interfering with the talking of the others was Carty's work. These are but a few of his many services.

Telephoning across the Continent

The telephone system grew with marvellous rapidity. In 1892 New York was talking with Chicago. The service was soon extended to Milwaukee, Omaha, and then it took a still longer stride to Denver. But, like the famous beanstalk of fairy lore, the genie of the telephone system did not stop. Presently the dream of transcontinental communication became a fact. Over the hills and valleys, across the plains, up the mountainsides, through the sagebrush, and down to the Golden Gate in less than a second is now a commonplace of the telephone romance.

Of tremendous importance to telephony was the invention of the "loading coil" by Professor Michael Pupin, of Columbia University. In 1874 Michael Pupin, a poor Serbian lad of fifteen, landed at Castle Garden, New York city, with only five cents in his pocket, and utterly unable to speak the English language. His first encounter with American life was in the shape of a fistic combat with Battery bootblacks, in which he demonstrated his superiority as an amateur pugilist. After a short period on a farm, where he learned to speak English, he returned to New York. Suffering the bitter experiences of poverty and wholly without influence, Pupin slowly worked his way through Cooper Union and Columbia University. He partially met his university expenses by giving lessons in wrestling and boxing. After further study abroad he came back to a professorship at Columbia, and has been a member of the faculty since 1888.

His first discovery was the "tuning principle" in wireless,

an invention which he sold to the Marconi Company for a large sum. His next and most important invention was the "loading coil" which first made it possible to telephone cheaply over long distances. It is not easy to explain just what is a "loading coil," nor what it does. Tie a heavy rope to a post; shake it with your hand ever so little, and a wave runs along the rope back and forth. Repeat the experiment with a thread. The thread must be shaken harder to obtain a similar wave. Suppose you hang weights from the thread and then shake it. Now it becomes easier to get a response, a wave. Pupin's coils are somewhat like these weights. They "load" the line and make it easier to send electric waves. The idea of so "loading" a telephone line was not original with Pupin. No one knew just where the coils should be placed. There were thousands of possible intervals, and it would have taken years to determine the correct intervals by actual experiment. Pupin worked out a mathematical formula, after many weary months, which told him exactly where the coils should be placed. The telephone company is said to have paid Pupin $500,000 for his American patent rights. He probably made as much more out of his European patents. In New York City alone, the Pupin coils save the telephone company $3,543,000 a year, because they made possible the substitution of small wires for large ones in telephone cables.

Another invention which has been of tremendous importance in the development of long-distance transmission as well as in many recent developments of the telephone, is the Lee De Forest vacuum-tube amplifier. This marvellous little device, described in the chapter on radio communication, has been brought to a high state of efficiency. It was invented by Lee De Forest in 1906, and patented a year later. It controls and magnifies the electric current sent out through the line, and following its introduction the human voice travelled from New York to San Francisco with remarkable clarity and speed.

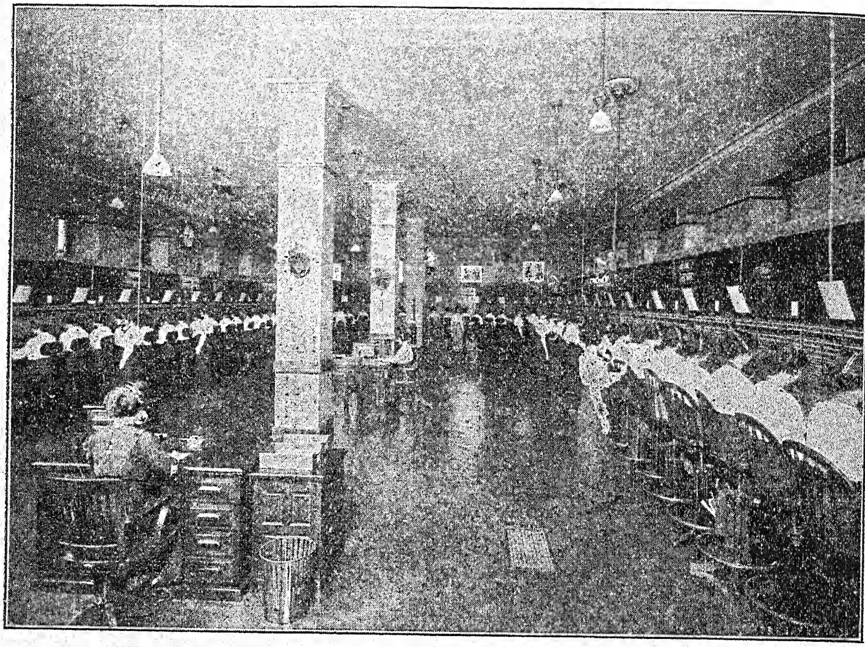
The transcontinental line, opened on January 25, 1915, is 3,390 miles long. At frequent intervals are vacuum-tube amplifiers, or repeaters. There are two circuits, each consisting of 6,780 miles of "hard drawn" copper wire, weighing 2,960 tons. In the loading coils of each circuit are 13,600 miles of fine

insulated wire only four thousandths of an inch in diameter. The line is strung on 130,000 poles and crosses 13 States.

ALEXANDER GRAHAM BELL OPENING THE NEW YORK–CHICAGO LINE, OCTOBER 18, 1892.

On the historic afternoon of January, 1915, Doctor Bell in New York speaking into an exact reproduction of his original instrument, was clearly heard by Watson in San Francisco.

Doctor Bell said again, as on that other historic day, thirty-nine years before: "Mr. Watson, please come here, I want you." And Watson replied: "It would take me a week now."



INTERIOR OF THE "CHELSEA" EXCHANGE, NEW YORK.

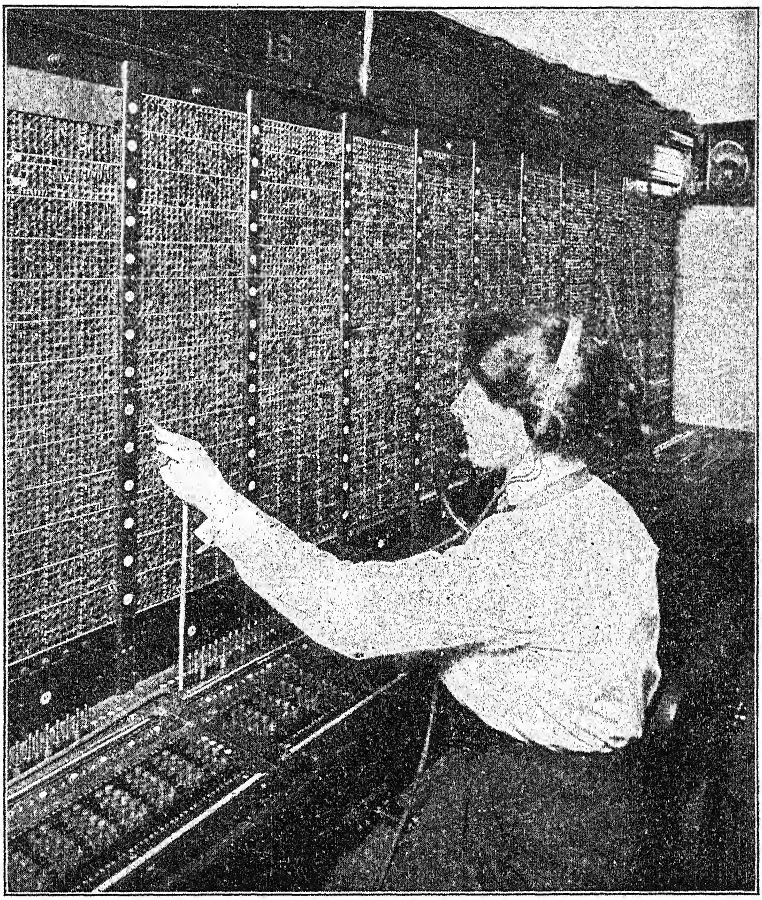
A modern multiple switchboard of this type may be 250 feet long. It is divided into "A" sections and "B" sections which are on separate sides of the room. The "A" sections handle only connections to be made with the exchange's own subscribers. Calls for subscribers connected with other exchanges are switched to the "B" sections. These manually operated switchboards will soon be obsolete, their place being taken by automatic machines.

What a magnificent chapter brimming over with glorious achievement and marvellous progress this incident closed!

By Wire and Wireless

Immediately following the triumph of transcontinental telephony, General Carty and his staff of engineers began the development of wireless communication in conjunction with wire-telephoning. How this was accomplished is told in detail in another chapter in this book dealing with radio. Success, however, was rapid and certain. On September 29, 1915,

Theodore N. Vail, sitting at his desk in New York, sent his voice by wire to Arlington, where it was amplified and transmitted to the great wireless naval station. From there, radiating with



MODERN MANUALLY OPERATED TELEPHONE SWITCHBOARD.

This is a detail of a "B" board. The operator is engaged in connecting a subscriber from another exchange with the subscriber called.

the speed of light in all directions, the boundless ether carried the electromagnetic waves to Carty at Mare Island, California, where he heard and conversed with Vail as easily as though they had been in adjoining rooms. The following day messages were picked up in Honolulu, 5,000 miles distant.

In May of 1916, Secretary Daniels, sitting at his desk in Washington, with magic ease and speed conversed at will with every naval station from ocean to ocean, and from the Gulf to the Lakes. Not only this, but the secretary, by wire and wireless, also talked with Captain Chandler of the *New Hampshire* off the Atlantic coast, and kept in communication with him for twenty-four hours.

In the spring of 1921, under the direction of Carty, telephone communication was opened by cable from Havana, Cuba, to Key West, a distance of 115 miles, thence by wire to Washington, New York, San Francisco, and Los Angeles, and then by wireless 29 miles to Catalina; a total distance of 5,500 miles. This is the longest submarine telephone cable in the world.

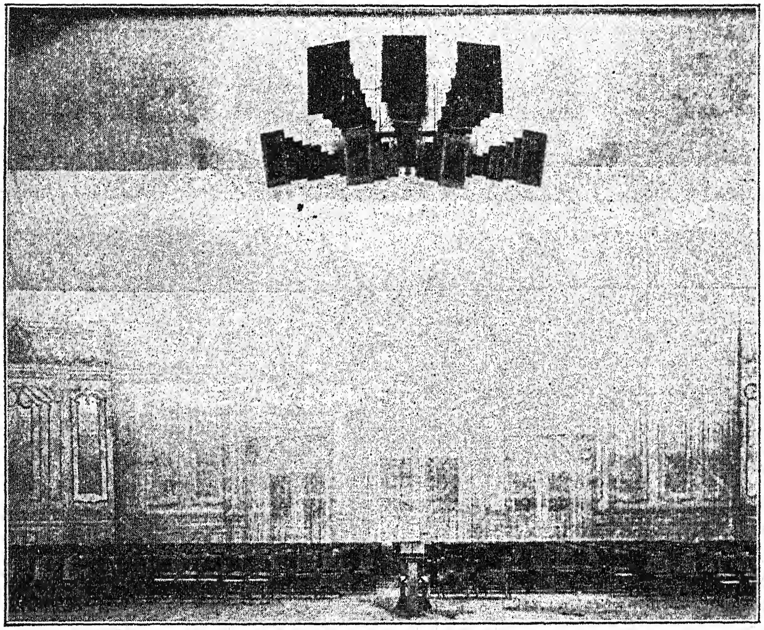
Late in 1918, Theodore N. Vail announced the invention of the "Multiplex Telephone," by which five conversations might be carried on over the same circuit at the same time, four in addition to the one provided by the ordinary methods. Five messages travel over a common pathway and yet are completely separated at the other end. All this has been accomplished by means of magical vacuum tubes, each so adjusted that it receives only the words (currents) intended for it, and sends them along. Each voice current impresses itself upon its own "carrier current" and passes over the common line; yet the voices never intermingle. Millions of dollars are thus saved in copper wire to carry separate voices.

Some Facts and Figures

The telephone "talk tracks" of the nation measure approximately 33,200,000 miles of wire, 60 per cent of which are in underground cables. The copper in them weighs 700,000 tons; the overhead wires are strung on 30,200,000 poles. The wires in the underground cables along Broadway, New York city, if put on poles would require ten pole-lines, each as high as the Woolworth Building, with the cross arms two feet apart and ten wires to the cross arm.

The people of this country talk with one another at the rate of 18,250,000,000 completed telephone conversations per year, in addition to 3,000,000,000 conversations originated but not

completed. In New York during the busiest hour of the day, from 10 A. M. to 11 A. M., more than 450,000 calls are originated and answered by the operators in the various exchanges of the city. In New York alone there are 950,000 telephones, and 3,341,000 miles of wire, weighing 65,000 tons. The em-



LOUD SPEAKER INSTALLED IN THE AUDITORIUM THEATRE, CHICAGO, DURING A CONVENTION.

The orator talks from the desk. A transmitter picks up his voice. The voice is amplified and projected into the hall by the big horns above. It is possible thus to address audiences numbering fifty and even a hundred thousand, if they could be packed into an auditorium. Fully 50,000 persons have distinctly heard orations out of doors on this principle.

ployees engaged in the telephone service of the metropolis would make a city of 28,300 population. About 4,000,000 directories are distributed to the public each year. These directories weigh 7,800 tons, and require an army of 500 men to do the work of distribution.

What the telephone means to the world no man can correctly gauge. It has established a miraculous communication. It has banished isolation. Ocean now sounds to ocean, and continent

to continent. The business, political, and social life of the nation and of the world courses over the telephone circuits and spreads through the ether.

In less than a half-century the first feeble cry of the baby telephone grew into a voice which could be distinctly heard throughout the length and breadth of the nation.

CHAPTER V

SIGNALLING AND TALKING BY RADIO

OUT of the horn or "loud-speaker" of the radio receiving-apparatus wells the voice of a baritone, singing the prologue from "I Pagliacci." It is as if he were in the room. How does his voice reach us? No wires connect the receiving instrument with the broadcasting station; it can not be a physical connection. The windows are closed; therefore, it cannot be the air. Besides, if it were the air, we would hear the voice in the street.

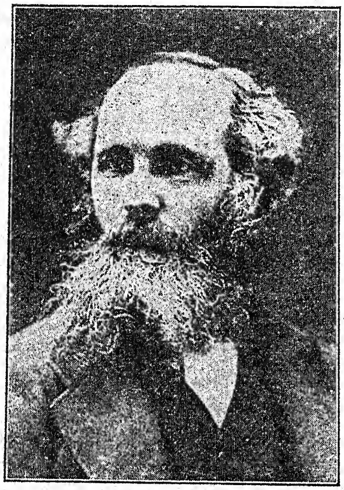
When we try to explain why we hear we are exactly in the position of scientists long before wireless communication was even a fantastic possibility. They were puzzled by light. What is light? Why does it reach us through the airless spaces that separate the earth from the blazing sun and the twinkling stars? Why does it pass through glass in which there is no air? At first, it was thought that light possibly consisted of minute particles shot forth by burning candles or glowing stars. Among those who held this view was Sir Isaac Newton. Because the theory could not account for the colors in the rainbow or the tints reflected from mother-of-pearl and the crystals of chandeliers, it was dismissed. Early in the nineteenth century, it was decided that light must be a wave motion in something. But in what? The scientists had to imagine a medium through which light travelled in waves, just as waves travel in water. This medium, which they called the "ether," is supposed to pervade all space. Everything is plunged in the ether, including the atoms of which air is composed.

Rock a boat from side to side, and waves are set up in water. Atoms must rock to set up in the ether the waves that we call light. We can rock a boat a few times a minute and set up waves in water, but an atom must rock many millions of times a second in order to generate ether waves that we call light.

When light was thus explained, it became easy also to ex-

plain its many hues. Color is to light what pitch is to sound—a matter of frequency of vibration. Violet corresponds to the highest pitch we can hear; the deepest visible red to the lowest audible pitch; and pitch, in turn, is dependent on the number of times something vibrates or rocks in a second.

All this and much more was known about light when Michael



JAMES CLERK MAXWELL. HEINRICH HERTZ.

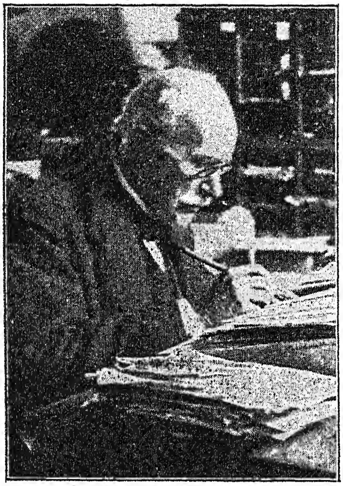
Maxwell was an English physicist who first mathematically demonstrated the possible existence of the waves now used in radio communication.

Hertz was a German professor who experimentally verified Maxwell's prediction of the existence of invisible electromagnetic waves in the ether of space—the waves now used in radio communication.

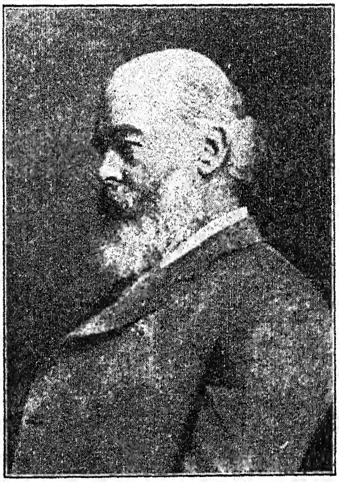
Faraday (1791–1867), who, according to Du Bois Reymond, an eminent German scientist, was "the greatest experimentalist of all times, and the greatest physical discoverer that ever lived," began to study an electrical phenomenon which he called "induction," and found out much about it that we now apply in radio communication.

In the whole history of science and invention, no more appealing example of devotion to truth-seeking, of self-denial, energy, and resourcefulness is to be found. Other great scientists had the advantage of a solid education. Faraday had no education whatever, in the collegiate sense. He even had to teach

himself how to read and write. When, as a bookbinder's apprentice, he did learn to read, instinctively he turned to works on chemistry and electricity; which books prompted him to action. He repeated the experiments described in the books, going so far as to make himself an electrical machine with a glass bottle as a foundation. And all this before he was four-



DOCTOR EDOUARD BRANLY.



SIR OLIVER LODGE.

Long before the days of the crystal and vacuum-tube detector Branly invented a detecting device known as the "coherer." This device was simply a glass tube filled with metal filings, which cohered when the current from the receiving antenna passed through them, and therefore became conducting, and which were "decohered" by tapping them. Marconi used such coherers in his early receivers.

Lodge introduced the principle of tuning (syntonization) in radio communication.

teen. His copious, boyish notes of lectures that he attended are still preserved in the library of the Royal Institution: mute testimony of a dauntless spirit struggling against the enormous odds of poverty and lack of education to acquaint itself with the science of the day. Such was Faraday's thirst for knowledge that he was willing to forego all hope of gain. He wrote to Sir Humphry Davy asking for a post of some kind in the Royal Society. "What can I do?" said Davy, when he read his letter. "Do?" queried the man to whom he addressed himself. "Do? Put him to washing bottles."

But Davy did more than that. Faraday was engaged at the pittance of twenty-five shillings a week to "attend and assist the lecturers and professors for and during the lectures," and to make himself generally useful. His rise from a laboratory nonentity to the foremost scientific figure of his time was rapid.

The part that Faraday played in the discovery of electrical principles is dwelt upon in the chapter on electricity. In that chapter Oersted's discovery is mentioned—the discovery that an electric current in a moving wire can affect a magnetic needle. Faraday began to think of the experiment. It proved that there is some relation between electricity and magnetism. If an electric current could influence a magnet, could a magnet, conversely, generate a current in a dead wire? Faraday thought so. It took him seven years to obtain the evidence that he sought. One day he thrust a bar magnet into a coil of wire with which an electrical indicator (a galvanometer) was connected. The needle of the instrument swung in one direction when the magnet was inserted, and in the other when it was removed. A current had clearly been "induced" in the dead coil, as the instrument proved. He found, too, that a moving electrified wire could similarly "induce" a current in a dead wire with which it was not in contact.

How was this phenomenon to be explained? This seemed to be a case of "action at a distance." Yet the effect of the bar or of the current in the live wire had to be transmitted by something. "Action at a distance" was a phrase that explained nothing. Faraday showed that the action, whatever it was, always occurred along definite lines, but the "something" by which the action was transmitted through space he could not divine.

Maxwell Begins His Study of Electric Waves in Space

It remained for another great Englishman, James Clerk Maxwell, to reveal the true nature of the "something," the medium that transmitted electrical effects through space. Maxwell was primarily a mathematician. He reasoned rigorously on paper with symbols and formulas. Unlike Faraday, he was

a graduate of a university, in fact, of two universities: Edinburgh and Cambridge. Maxwell was a born mathematician, and at fifteen he was making contributions to higher mathematics. He thought mathematics by day, and dreamed mathematics by night. Doctor Garnett, his biographer, thus describes his curious habits at one time of his life:

"From 2 to 2.30 A. M. he took exercise by running along the upper corridor down the stairs, along the lower corridor, then up the stairs, and so on until the inhabitants of the rooms along his track got up and laid *perdus* behind their sporting doors, to have shots at him with boots, hair-brushes, etc., as he passed."

So attracted was this profound mathematician by Faraday's work, that an article of his contributed to the ninth edition of the Encyclopedia Britannica remains to this day one of the most eloquent and just appraisals of Faraday's position as an experimental scientist.

It was the mathematical explanation of Faraday's discovery of induction, the revelation of what the mysterious "something" is that transmits electrical effects at a distance, with which Maxwell's name is immortally linked. He read Faraday's description of the induction experiments with something like deep, religious reverence. He saw how little the great experimentalist relished the idea of "action at a distance."

Maxwell thought that electricity might possibly be transmitted by that same ether which scientists had created in their minds to explain the transmission of light. He undertook a profound mathematical study of the way in which light flashes through space. He was irresistibly forced to the conclusion that light waves are electromagnetic waves. But Faraday was also dealing with electromagnetic waves.

Might there not be electromagnetic waves that could be seen, what was called "light," and also electromagnetic waves that could not be seen? Was that the explanation? And was the "something" that transmitted Faraday's effect through space, nothing but the old, familiar ether? The questions almost answered themselves. Maxwell boldly announced that Faraday's "something" that "induced" electrical effects at a distance was nothing but the ether. It was known that light travelled at the stupendous rate of 186,000 miles a second.

Maxwell predicted that if the electrical wave motion with which Faraday experimented could be measured, it, too, would be found to travel at the speed of 186,000 miles a second. He even went so far as to maintain that the electric waves could be reflected and refracted like light.

Maxwell developed this view in a classic book of his called *Electricity and Magnetism*, which appeared in 1873. Such was his reputation in Europe as a leading mathematician of his time, such was the convincing nature of his mathematical proof, that his theory was accepted.

And yet, it was only a theory. No one realized this better than Maxwell, but so sure was he of his conclusions that he looked forward with confidence to the experimental proof of his views. He did not live to see them triumphantly vindicated; for he died in 1879 when only forty-eight.

Why can we see the electromagnetic waves that we call light but not the electromagnetic waves with which Faraday experimented in his induction researches? For the same reason that we can hear only a few notes. If a sound consists of less than sixteen vibrations a second, we hear merely its separate thuds; if it consists of 10,000 vibrations a second we hear it as a very shrill, high-pitched note; if it consists of more than 32,000 vibrations a second we cannot hear it at all. Something must rock or vibrate at least 400 million million times a second in order that we may see what we call light. But the waves about which Maxwell reasoned mathematically are produced when something rocks or vibrates 10,000 to 3,000,000 times a second. In other words, some electromagnetic waves could not be seen because they were generated at frequencies so low that the eye could not respond to them. Stated in another way, Maxwell's waves cannot be seen because they are too long; for the length of a single wave may be anything between a few inches and a score of miles. On the other hand, the waves of visible light are so short that from 30,000 to 60,000 of them are compassed within an inch.

Hertz Invents an "Eye" to See the Invisible Waves

What was needed, then, was not only a way of generating these invisible waves, but a kind of artificial eye which would

see them. After Maxwell had published his startling theory, scientists in several countries tried hard to render them visible. The successful man was Heinrich Hertz, a modest German professor at the university of Bonn, who freely acknowledged his debt to Maxwell, and who was so self-effacing that he went so far as to declare that had he not experimentally confirmed Maxwell's conclusions, another Englishman, Sir Oliver Lodge, would surely have done so.

Hertz' experiment is so simple that it seems astonishing that it was not made before his time (1887). He created electric sparks, little flashes of artificial lightning in his laboratory. At the opposite end of the laboratory he mounted what he called a "resonator": a metal ring not completely closed, and therefore provided with a little gap. When sparks crackled in the sending apparatus, tiny answering sparks crackled in the gap of the ring. This in itself did not prove that light and electromagnetic waves are one and the same, as Maxwell maintained. But Hertz proved that the waves were reflected from suitable surfaces just as light is reflected from a mirror.

The whole scientific world was aroused by Hertz' confirmation of Maxwell's theory. In France, in England, in Russia scientists began to study these newly discovered waves, which, fittingly enough, were christened "Hertzian waves." To detect them, artificial eyes were invented, far more delicate than Hertz' simple open metal ring or resonator. Popoff, the Russian, at once began to study lightning; for lightning is a gigantic spark which also sends waves that can be detected. Lodge, in England, and Branly, in France, performed notable experiments, all of which did much to add to our knowledge of the waves.

And yet, not one of these distinguished scientists realized that waves in the ether might be used to send intelligible messages over a great distance. Perhaps they were too engrossed in the purely scientific aspects of their work to bother about the practical application of theories; perhaps it was because the distance over which they could transmit waves—a few hundred feet—did not fire the imagination. Long after radio communication was an established fact, Lodge wrote frankly that, so far as he was concerned, he "did not realize that there would be a practical advantage in . . . telegraphing across space. . . .

In this non-perception of the practical uses of wireless telegraphy, I undoubtedly erred."

It was Sir William Crookes who first saw that the waves about which Faraday and Maxwell had theorized, and the existence of which had been proved by Hertz, might be practically applied in signalling through space. In a memorable article published in the *Fortnightly Review* in 1892, on "Some Possibilities in Electricity," he wrote:

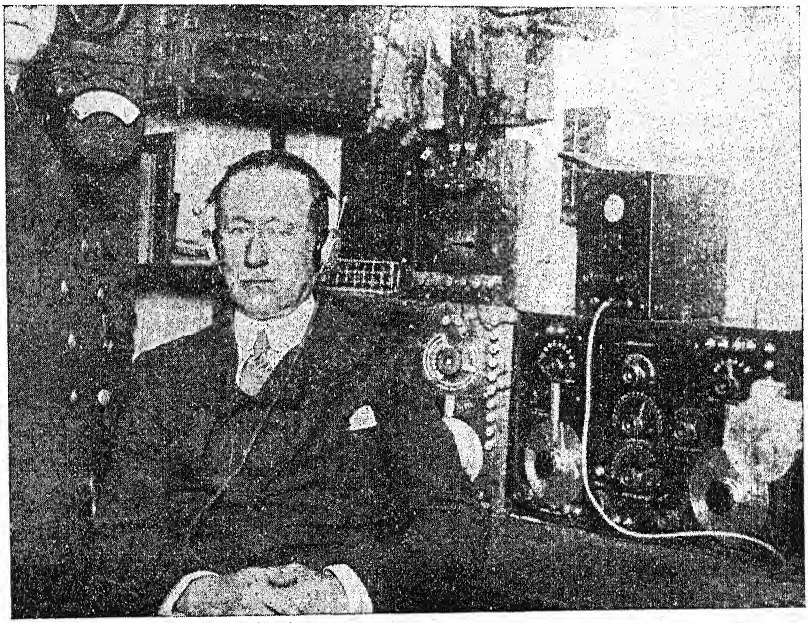
"Here is unfolded to us a new and astonishing world—one which it is hard to conceive should contain no possibilities of transmitting and receiving intelligence. Rays of light will not pierce through a wall, nor, as we know only too well, through a London fog. But the electrical vibrations of a yard or more . . . will easily pierce such mediums, which to them will be transparent. Here, then, is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present appliances. . . . What, therefore, remains to be discovered is—firstly, a simpler and more certain means of generating electrical rays of any desired wave-length, from the shortest, say of a few feet in length, which will easily pass through buildings and fogs, to those long waves whose lengths are measured by tens, hundreds, and thousands of miles; secondly, more delicate receivers which will respond to wave-lengths between certain defined limits and be silent to all others; thirdly, means of darting the sheaf of rays in any desired direction, whether by lenses or reflectors, by the help of which the sensitiveness of the receiver . . . would not need to be so delicate as when the rays to be picked up are simply radiating into space in all directions, and fading away. . . .

"Any two friends living within the radius of sensibility of their receiving instruments, having first decided on their special wave-length and attuned their respective receiving instruments to mutual receptivity, could thus communicate as long and as often as they pleased by timing the impulses to produce long and short intervals on the ordinary Morse code."

It would be difficult to present a more accurate picture of radio communication both in principle, as well as in practice, than this.

Marconi's First Experiments

Such was the "state of the art," as patent lawyers say, up to 1896. Electric waves had been sent out into the ether and "seen" by special "eyes" or detectors. Crookes foresaw the possibility of telegraphing through space, but no one had actually done so. And then a mere boy began a series of experiments that culminated in a complete realization of Crookes'



Courtesy Radio Corporation of America.

GUGLIELMO MARCONI, INVENTOR OF WIRELESS COMMUNICATION.

prophecy. He was Guglielmo Marconi, the son of an Italian father and an Irish mother.

In 1896, Marconi, then but twenty-two, received his first patent. In that historic document is disclosed what now seems an obvious invention. At the sending station was the familiar Morse key; at the receiving station the equally familiar receiving apparatus, in which a detector (Branly and Lodge's form of "eye") was included. The Morse key was depressed. Sparks passed. They sent out waves into the ether. The key

was released. The sparks and the waves ceased. Thus long or short trains of waves were sent out, corresponding with the dashes and dots of the Morse code. The receiver responded sympathetically. The eye or detector "saw" while the key was down; it saw nothing when the key was up. It received invisible telegraphic flashes.

Marconi had improved on Hertz' original sender so considerably that when he demonstrated his invention before the British post-office officials in 1897 on Salisbury Plain, he transmitted signals four miles. And yet there was not a single original element in his apparatus. This is not said to his discredit. Morse's telegraph, indeed every epoch-making invention, is usually a new combination of old elements, producing a new result. That Marconi is a great inventor, that he has the imagination that always makes great inventors, is proved by the mere fact that, for all their great attainments, Hertz, Branly, Lodge, and Popoff never dreamed of signalling through space, although they were experimenting with the electromagnetic waves almost daily for long periods.

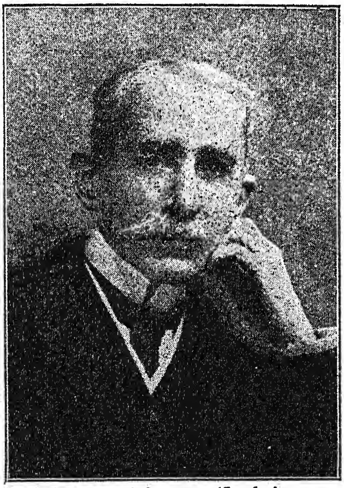
Marconi discovered that his range could be increased if he elevated the wire constituting part of the sending circuit and connected it with the ground. Thus elevated, the wire looked for all the world like the feeler of some gigantic insect, and hence it came to be called an "antenna." Wires were similarly elevated at the receiving station with corresponding good effect. In his early work Marconi even used kites to carry his wires far up into the ether. The great transoceanic stations of to-day have antennæ that reach up several hundred feet; indeed, the towers on which they are carried may be as tall as office buildings.

By the end of 1897, Marconi was signalling nine and ten miles. "Half a mile was the wildest dream," said Sir William Preece of the British post-office, in commenting upon the hopes of the more optimistic who believed in Marconi.

Sir Oliver Lodge Discovers the Principle of Tuning

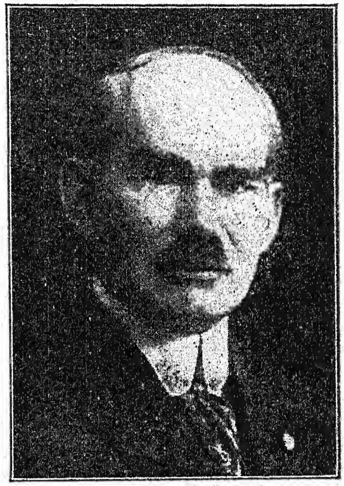
The sun sends out waves of what we call white light, which is, nevertheless, a mixture of all the colors in the rainbow. Sunlight is the equivalent of a noise. A red light is the equiva-

lent of a single musical note because it consists of vibrations of one period only. Marconi's sparks were like flaming candles or matches compared with the sun—much the same in color but less dazzling. They were little noises. It occurred to Sir Oliver Lodge in 1897 that a new principle might be introduced. Why not send out a beam of wireless waves which would be the



Courtesy Marconi Company (London).

JOSEPH A. FLEMING.



LEE DE FOREST.

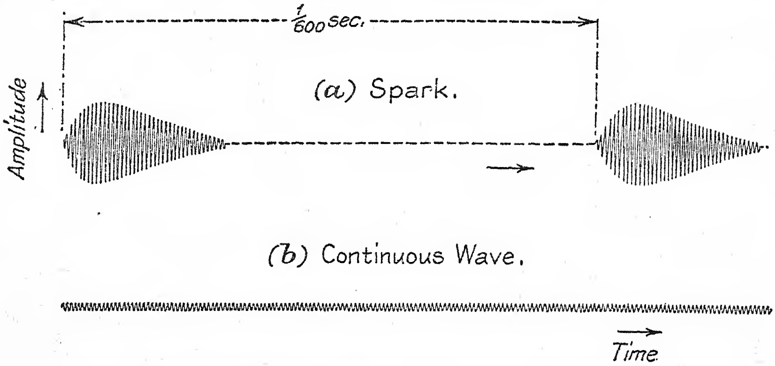
Fleming, an English engineer and physicist, who first applied the "Edison effect" in receiving wireless-telegraph signals.

De Forest invented the modern vacuum-tube, one of the most remarkable inventions ever made in electricity.

equivalent of a musical note or of one color of light? Hold a vibrating tuning-fork near a piano, and only that string of the piano which corresponds in pitch with the tuning-fork will vibrate in sympathy. Or, put on a pair of red spectacles and all the world seems red. It is easy to see that Sir Oliver Lodge had the principle of tuning in mind. He wanted to send out waves of one electrical pitch only, and tune the receiving instrument so that it would respond to that pitch and to no other. This Lodge did by adjusting the sending and receiving apparatus to what is called the "wave-length."

We have only to recall the waves of the ocean to realize the possibilities. By "wave-length" is meant the distance from

the crest of one wave to the crest of the next in the same train. The distance is large for big waves and small for little waves. The larger the waves or the greater the wave-length the more slowly do they travel. This means that fewer of them strike the receiver per second, whether the receiver be an eye, an ear, a beach, or a wireless detector. If they are few, we have a deep electrical note; if they are many, we have a high electrical



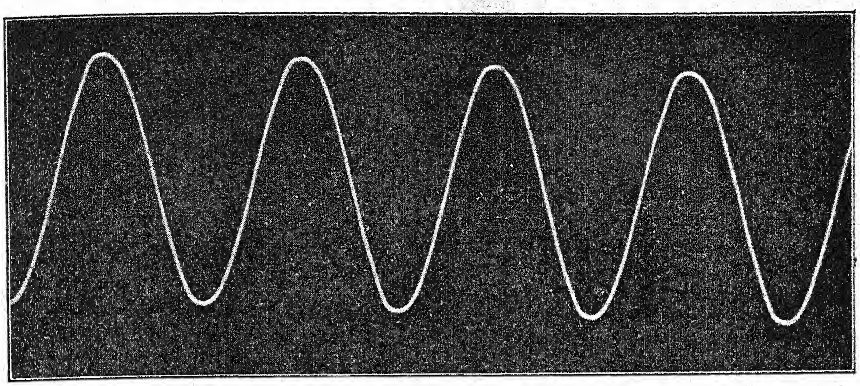
DAMPED AND CONTINUOUS RADIO WAVES.

A spark sends out damped waves, which die down. What is needed for radio telephoning is a continuous wave which persists.

note. Lodge converted the wireless transmitting station into something like a tuning-fork that sends out waves of one note only. The receiving station could be attuned to that note and could thus exclude the signals that came from stations that were not using it.

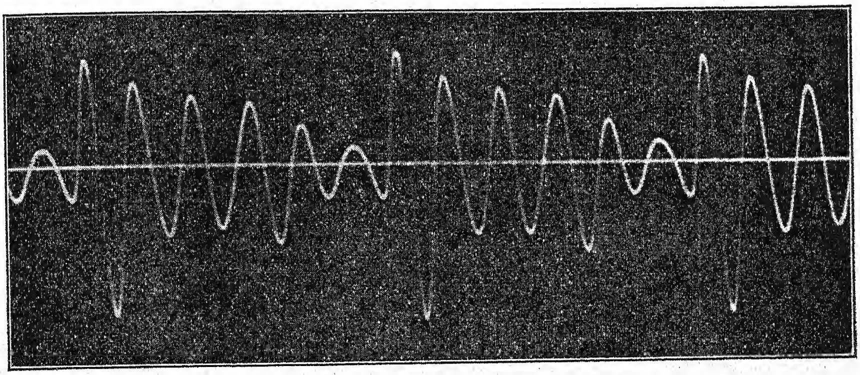
This marked an enormous advance in wireless communication. A station could send one wave-length or electrical note to another station. The receiving station, knowing on what wave-length the transmitting station was sending, could "tune in" or vibrate in electrical sympathy.

The wave-length in radio communication may be anything from 1 to 50,000 metres. In radio communication, wave-lengths are always stated in metres. Translate these wave-lengths into ordinary language and compare them with other waves and their extraordinary character becomes immediately apparent. The waves of the ocean may measure a few inches or several hundred feet. But the waves which are sent billowing through



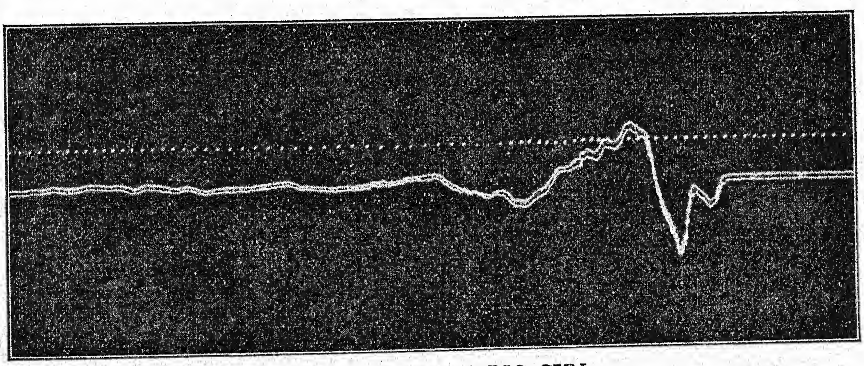
THE SIMPLEST SOUND-WAVE.

Photograph made by Professor Dayton D. Miller of the sound-wave produced by a tuning-fork in vibration.



THE WAVE PRODUCED BY A FRENCH HORN.

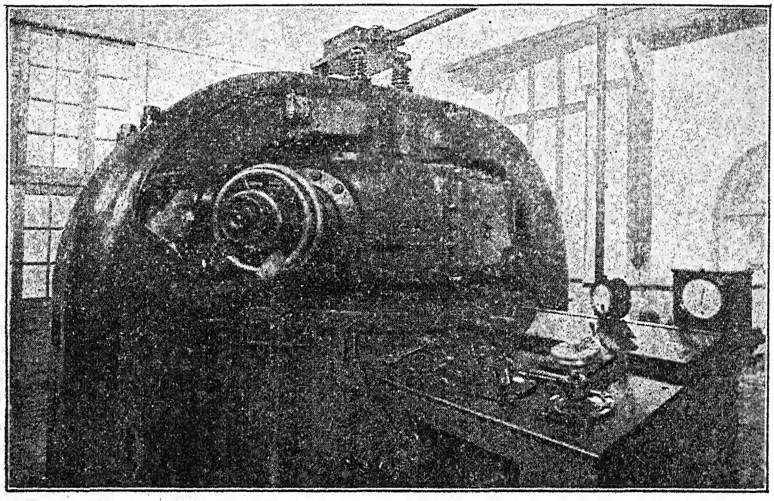
The photograph was made by Professor Dayton D. Miller, of the Case School of Applied Science. It shows about the simplest type of wave produced by a musical instrument.



THE NOISE OF A BIG GUN.

A noise-wave is erratic, as this photograph shows; a musical note is always of more or less regular wave conformation.

the ether by a transatlantic radio station may measure from four to twenty miles from crest to crest. For short distance transmission the length of the wave may measure a few inches up to several hundred feet. Since he was dealing with waves



ARC OF THE BORDEAUX STATION.

Within this casing is an arc which resembles the arc that glows over many a street corner. But this arc is very much larger and is prevented from breaking or being extinguished by a very complicated arrangement of magnets. Arcs of this type were used for radio telephoning by the Danish engineer Valdemar Poulsen.

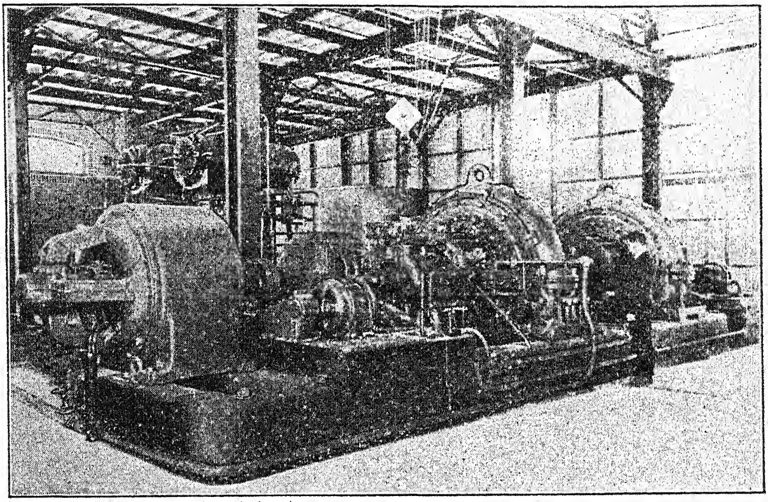
that varied so widely in length, Lodge had devised a method of sending and receiving which had enormous possibilities.

Marconi's Progress

Marconi soon made arrangements with Lodge to apply this method of tuning to wireless telegraphing, with the result that he vastly increased the effectiveness of his system of communication. By this time, the Wireless Telegraph and Signal Company had been organized in England to buy Marconi's rights. The Italian navy adopted wireless telegraphy. By 1898 Marconi had established wireless communication across the English Channel, and had also reported the International Yacht Races between Sandy Hook and the office of the New York *Herald;* both considered marvellous exploits at the time. The

principal steamship companies equipped their vessels with Marconi wireless sets, and many a ship in dire distress was saved by their means.

Greater and greater distances were covered. In 1900 Marconi made a great advance. He devised a way of sending out



Courtesy Radio Corporation of America.

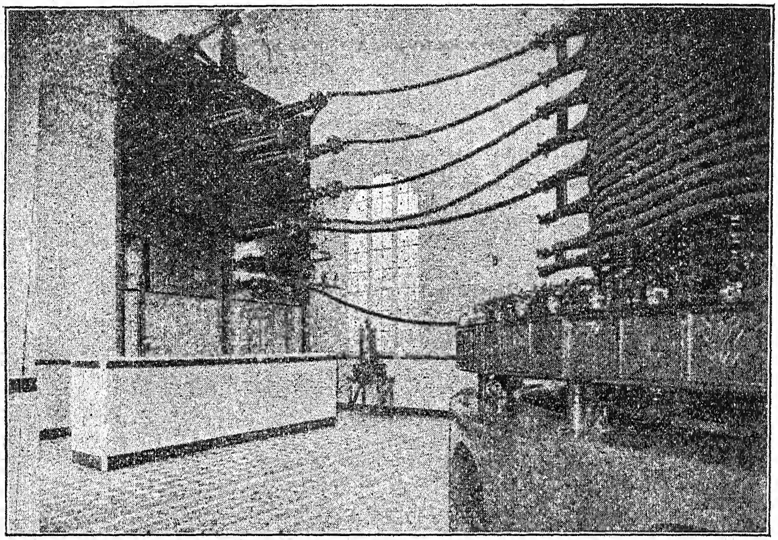
THE ALEXANDERSON ALTERNATOR.

This machine looks like an ordinary generator, such as may be found in every electric central station. It is not an ordinary generator, however, but an Alexanderson alternator, especially built to generate the high-frequency currents used in radio communication. These alternators have already given place to vacuum-tubes.

powerful prolonged trains of waves. He tuned his receiver to the transmitter so that the detector was not easily affected by a single wave, as heretofore, but only by a train of waves of suitable frequency, thus extending Lodge's principle. After having succeeded in telegraphing with this system a distance of 200 miles, he decided to bridge the Atlantic. But he needed more power. His chief engineer, Professor J. A. Fleming, designed the stations. A less courageous spirit than Marconi's would have been daunted by the accidents that occurred in erecting tall aerials. Towers and masts were blown down by storms. It seemed almost hopeless for a time to triumph over nature. Finally, with the aid of kites flown at Newfoundland, Marconi,

on December 21, 1901, received from Poldhu, Cornwall, the three dots representing the letter "s."

Refinements were now rapidly introduced to make transatlantic communication more efficient. Marconi invented a magnetic detector, which made it possible to hear the dots and dashes as musical notes of shorter or longer duration, and at



INTERIOR OF THE LAFAYETTE STATION, FRANCE.

The size of the wire is an indication of the amount of power that is radiated. To the right is a high-power tuning-coil.

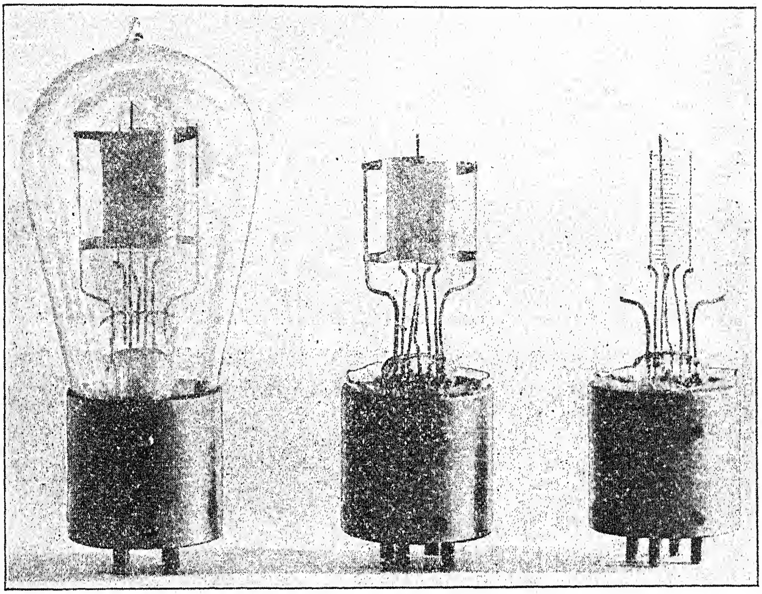
once the speed of reception was increased to 150 letters a minute. Gigantic waves were shot out into space; waves measuring from four to ten miles from crest to crest.

Professor Fleming Invents the Oscillating Valve

The sparks or miniature artificial lightning flashes that Marconi used sent out waves that produced currents in the receiving antenna. The current oscillations ran up and down the wire at the rate of half a million to a million a second. The ordinary telephone, connected with the antenna, cannot respond to such rapid vibrations; hardly has the diaphragm begun to move when it is struck by another impulse. It occurred to

Professor Fleming that something like a valve was needed, something that would let current pass in one direction but not in the other. Thus every other oscillation that ran up and down the antenna would be suppressed, and the telephone would become more responsive.

In the early eighties Fleming held the post of scientific adviser to the Edison Electric Light Company, organized to de-



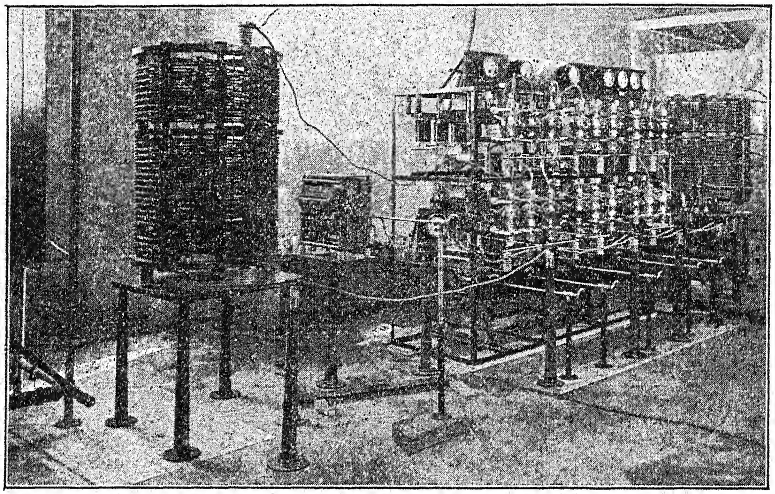
Courtesy General Electric Company.

FIVE-WATT TRANSMITTING-TUBE COMPLETE AND DISMEMBERED.

velop and introduce Edison's system of incandescent lighting in England. Naturally, he was thoroughly acquainted with Edison's researches.

Fleming recalled some experiments which Edison had made in 1883 and which had given the world what was known as the "Edison effect." For some reason, Edison had sealed within one of his incandescent-lamp bulbs a little plate of metal. There was no contact between the metal and the filament of the lamp; yet, when the filament glowed, a current would stream over from it to the plate, but only when the plate was positively charged. This was the "Edison effect." The discovery lay

dormant twenty-one years, unapplied. It flashed upon Fleming that this device of Edison's constituted the very valve that he wanted. "Suppose," he reasoned, "I use this lamp in my receiving circuit. Positive and negative currents rush up and down the antenna. When a positive impulse passes through the metal, current will stream over from the filament; but when



Courtesy Marconi Company (London).

VACUUM-TUBES IN A MODERN RADIO TRANSMITTING STATION.

the negative impulse immediately following strikes the metal, nothing will stream over."

He made the experiment. It proved brilliantly successful. Thus, in 1904, the Fleming "oscillation valve," as it has ever since been known, was introduced in radio communication. It was the first of the modern radio vacuum-tubes. By its means, trains of very rapid oscillations were converted into spurts of electricity, all travelling in the same direction. The result was that the reception of telegraph signals was enormously improved.

In 1906, General H. H. C. Dunwoody, of the United States Army, discovered that certain crystals (carborundum, for example), also had the property of suppressing one-half the waves that rush up and down the antenna. Because such crystals are cheap, because there is no necessity for lighting a lamp, they are

widely used to this day. The cheaper radio telephone-receivers in these days of radiated music and lectures are fitted with such crystals.

Courtesy General Electric Company.

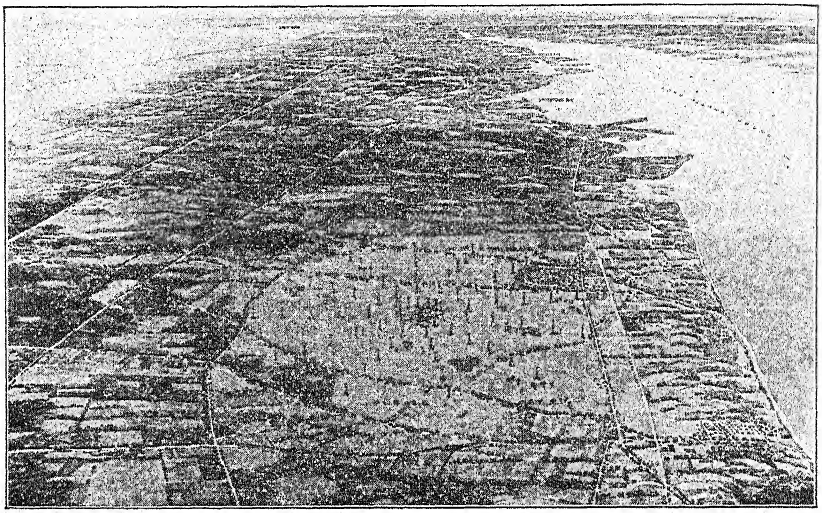
LITTLE AND BIG VACUUM-TUBES.

In one hand Doctor Langmuir is holding a small vacuum-tube of the type used in many radio sets for receiving broadcast speech and music; in the other he is holding a large twenty kilo-watt vacuum-tube used for generating waves in the ether of space.

De Forest's Remarkable Discovery

Remarkable as was Fleming's invention of the oscillation valve, still more remarkable was the improvement made by Lee De Forest, an American radio engineer. About 1906 De Forest inserted a tiny metal grid between the glowing filament

of the lamp, or tube, and the metal plate. When the grid was negatively electrified, current would not stream over from the filament through the meshes and on to the plate; but when the grid was positively electrified, the current rushed through the meshes and the plate was charged. The introduction of a grid between the filament and the metal plate does not seem much



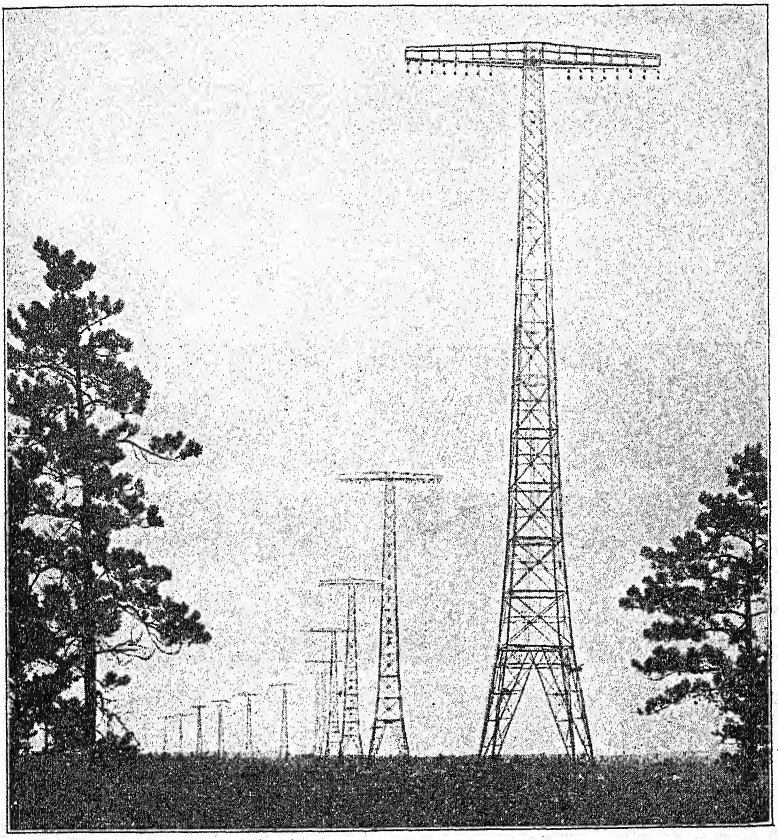
Courtesy Radio Corporation of America.

"RADIO CENTRAL" AS IT WILL APPEAR WHEN COMPLETED.

Twelve lines of towers radiate from a central power-house, each line pointing to a particular part of the world. Thus waves can be sent out which are destined for any country in Europe, Asia, South America, Africa, or the Southern Pacific. The towers, each about as tall as an ordinary office building, carry the antennæ.

of an improvement; yet De Forest's invention is as great as that of radio communication itself. De Forest had only to include his little grid in the receiving circuit. As it was now positively and now negatively electrified, it assisted or arrested the stream that tried to flow from the filament. He had only to connect his metal plate with a telephone-receiver to hear the signals with wonderful clearness. The little grid acted much like the throttle of a locomotive: it set powerful local currents in action, just as a locomotive throttle has only to be moved one way or the other to start or stop a freight-train. What is more, these currents in the receiving circuit were simply a

magnification of those that ran up and down the antenna. De Forest could add another lamp or tube to the first and obtain still louder effects. Thus, by adding tube to tube he could



Courtesy Radio Corporation of America.

THE TOWERS OF "RADIO CENTRAL," PORT JEFFERSON, LONG ISLAND.

One of the twelve lines of steel towers on which the antennæ of the great station of the Radio Corporation of America at Port Jefferson, Long Island, are carried. Each antenna consists of sixteen bronze cables, stretched horizontally from tower to tower. When the station is completed there will be 300 miles of cable. Each tower is 410 feet high, and the cross-arm or bridge which supports the antenna wires at the top is 150 feet long.

magnify a signal millions of times. It is easy to see what this meant in radio communication. Signals too feeble even for detection by Fleming's valve could be clearly heard by a De Forest tube or two; the receiving range was increased several times. All the great feats of long-distance radio communica-

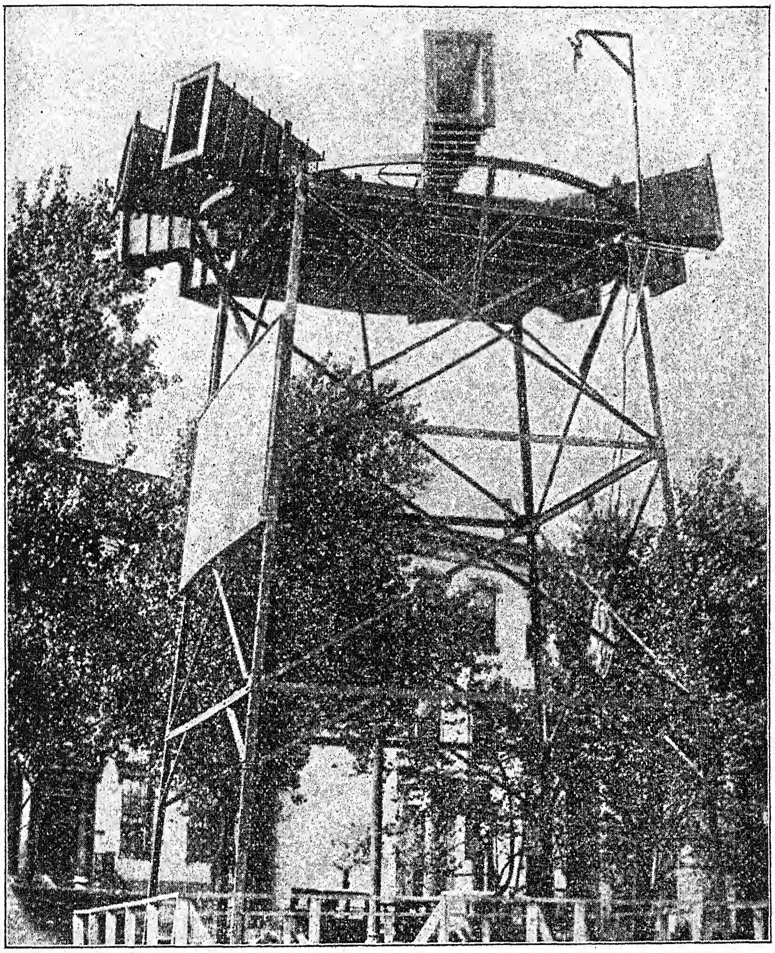
tion, feats that involve telegraphing half-way around the world, have been performed with this marvellous device, "the master weapon of the radio engineer," as it has been called.

De Forest's invention was at once applied in long-distance wire telephoning. Here was a device which made it possible to amplify feeble voice-currents just when they were beginning to vanish altogether. By inserting De Forest's tubes at intervals in the line it became possible to telephone from New York to San Francisco. It was thus that the electric current that carried President Harding's oration on the occasion of the interment of our Unknown Soldier in Arlington, Virginia, was multiplied 3,000,000,000,000,000,000,000,000,000 times. Amplified 10,000,000,000 times the President's words were heard by thousands in Madison Square Garden, New York. Higher amplifications were necessary in order that they might be heard in other cities. A De Forest tube can magnify the ticking of a watch until it sounds like a trip-hammer. Moreover, the tube makes it possible to transmit over a single telephone wire half a dozen different conversations without interference, each conversation being transmitted in waves of a definite frequency.

Armstrong and His "Feed-Back"

It was the World War that brought about the rapid development of the airplane, and it also made the radio-receiving set a household rival of the phonograph as a means of entertainment. War, wherein the lives of thousands of men are guarded, or imperilled, by superior scientific innovations, has always stimulated invention. A case in point was Edwin Armstrong, a young American, who held a major's commission. Even as a boy he had been interested in wireless telegraphy. Indeed, he was one of several hundred thousand American boys who built their own wireless sets, formed wireless clubs, and communicated with one another. When he was old enough to enter Columbia University he took the course in electrical engineering. There he came under the influence of Professor Michael Pupin, a man who has done as much as any other in America to shape the course of modern telephoning and radio communication. In 1912, while still a student, scarcely twenty-one years of age, Armstrong conceived the idea of making the

vacuum-tube of De Forest even more effective than it was. We must remember that in the tube a current streams from a



LOUD-SPEAKER FOR LARGE AUDIENCES.

In order that the speech of an orator may be heard in Chicago or New York by thousands, amplifiers of this type are mounted in auditoriums. The speech may be transmitted either over ordinary telephone-lines or by radio. The words of the distant orator are distinctly heard within a distance of one mile from this amplifier.

glowing filament through a grid to a metal plate, and that in the local circuit, of which the plate forms a part, magnified currents are obtained similar to those received by the antenna.

It occurred to Armstrong that he would take part of this current and "feed" it back, thus obtaining still stronger effects. If a machine-gun could take the bullets that it has fired and discharge them again, the process would be similar to that conceived by Armstrong. The invention was a wonderful success. With the "feed-back" of Armstrong, amateurs easily received signals from Germany, Honolulu, Darien, Norway, and the Philippine Islands. Since he used but few expensive tubes, his invention made it possible to manufacture receiving-sets of extraordinary sensitivity at a cost undreamed of before the war.

How Radio Telephony Developed

It was well-nigh impossible to telephone with the sparks that Marconi used. The waves they generated in the ether were not of the right kind. The first requirement for radio telephoning is a source of waves, constant in form; every wave must be like every other wave in length and height. Variations in the amplitude of the waves will introduce disturbances that prevent the effective transmission of speech. To appreciate how important is constancy of wave form, we have only to consider an ordinary swinging pendulum.

Set the bob in motion. The bob swings from side to side, but each swing or beat is of less amplitude than the preceding beat. Finally, the pendulum or bob "dies down." So it is in radio when a spark is used. The electrical vibrations, or oscillations, "die down." In a clock the pendulum is kept in motion by the energy of the wound spring; each beat is equal in amplitude to that of the preceding beat. These beats are continuous, or undamped, oscillations. The same phenomenon is observed in sound. Pluck the string of a violin and a short sharp note is heard that lives and dies in an instant. Draw a bow across a string and a note is heard that persists as long as the bow is in action. The plucked string emits damped sound waves; the bowed string undamped, or continuous, waves.

Marconi's damped waves, suitable enough for telegraphing, were useless for telephoning. This becomes even more evident when we consider the process that occurs when we telephone over a wire. As we say "Hello," we mould the electric waves that travel constantly through the wire into a "hello" pattern.

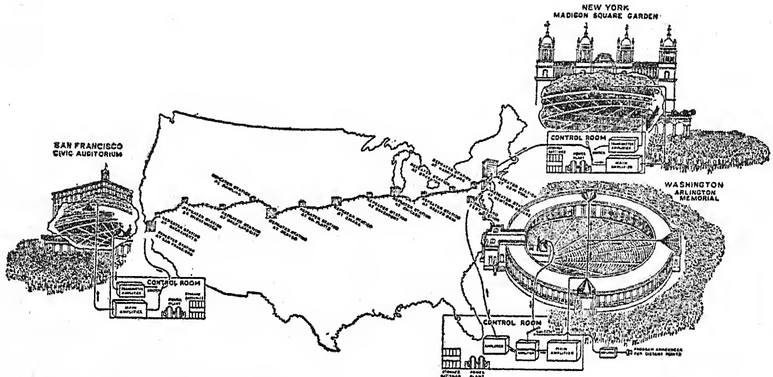
At the receiving end a diaphragm is caused to vibrate by the waves, and because they have been moulded by the voice into a "hello" pattern we hear the word "hello." The moulded wave corresponds with the sound-groove in a phonograph record. What we hear is not the actual voice but a reproduction in either case. So it is in radio telephoning. Substitute the ether for the wire and the rest of the process remains the same.

It can now be seen why it was difficult, if not impossible, to telephone through the ether with electric sparks. They were constantly dying down, and therefore could not be moulded by the voice. The diagram on page 362 shows the difference between damped and continuous waves in radio communication. Many devices were invented for the purpose of generating continuous or undamped waves by means of sparks, but in vain. Reginald Fessenden, an ingenious American engineer, tried using dynamos somewhat like those to be seen in modern power-houses. Nearly all electrically illuminated houses are supplied with what is called "alternating current." Water flows in a pipe in one direction, but an alternating-current dynamo generates current that travels through the wire in two directions, back and forth.

These alternations or oscillations of current are just what we need in order to set up waves in the ether. The ordinary alternating-current dynamo in the power-house is useless in radio communication. It produces electric oscillations or alternations that number about 120 a second, and rarely more than 500 a second. To generate waves in the ether something must rock back and forth not less than 10,000 times a second, and even as often as 3,000,000 times a second, as we have seen. The construction of a dynamo, generating a current which would swing back and forth in a wire with this increased rapidity, was an engineering feat that required designing ability of a high order. Fessenden pointed the way. Others improved on his method. Among them was R. Goldschmidt, a distinguished German radio engineer, and Doctor E. Alexanderson, a Swedish engineer, who became a naturalized American.

Their dynamos sent out waves that did not rapidly die away—continuous waves which could be moulded by the voice into a pattern that a telephone-receiver would reproduce. But

the machines were difficult to design and expensive to build. It occurred to the Danish engineer, Valdemar Poulsen, inspired by the suggestion of Duddell, an Englishman, that perhaps arcs might be substituted—arcs such as those that glow in many of our streets. Such an arc, he argued, was a permanent spark, not constantly formed and broken. But ordinary street arcs could not be used. They would fail to generate oscilla-



Courtesy Western Electric Company.

HOW PRESIDENT HARDING TALKED TO THE NATION.

When our Unknown Soldier was buried President Harding addressed a vast audience in the Arlington Memorial, near Washington. But far vaster was the audience than that gathered before him. New York and San Francisco heard him, too—thousands who were hundreds and hundreds of miles away. This marvellous performance was made possible by using the vacuum-tube as an amplifier and as a relay. The voice of the President was carried by telephone to New York, where it was heard by a throng that filled Madison Square Garden, and from New York was repeated, as shown on this diagram, in cities between the Atlantic and Pacific Oceans.

tions of many thousands per second. In 1903, Poulsen devised a special arc that met the requirements, and when that was done radio telephoning became easy.

But although dynamos and arcs are used both in radio telegraphy and radio telephony, the vacuum-tube of De Forest has already taken their place; for the tube can be used not only to receive and amplify the feeble waves that come from some far-distant station, but also to generate continuous waves. The time is rapidly approaching when dynamos, arcs, and sparks will all give place to tubes. Only continuous waves will be used, even for telegraphing over short distances. The same

transmitting station will, therefore, serve both for telegraphing and telephoning, just as receiving instruments now reproduce the dots and dashes of the Morse code and the human voice.

As soon as a method of generating continuous waves, waves that would not die away, was discovered, it became easier to transmit speech through the ether. Since Reginald Fessenden was one of the earliest of these successful experimenters, it was but natural that he should have been the first to transmit speech by continuous waves. As early as 1903 he had succeeded in telephoning a distance of about a mile. In 1906 he increased this distance to ten miles. From that year on, as the action of De Forest's vacuum-tube was better understood, progress was rapid. In 1915 a record was made. The human voice was transmitted from Arlington, near Washington, D. C., to Honolulu. And now we have radio broadcasting stations by which music, lectures, news, and stock-market reports are sent out for hundreds of thousands to hear.

In a sense, broadcasting has always been with us. Every radio station radiates its messages, whether they be telegraph signals or spoken words, into space. Any one who has the proper electromagnetic ear can hear them. But not until 1920 was broadcasting placed upon a permanent commercial basis. It occurred to a few imaginative engineers of the Westinghouse Electric and Manufacturing Co., that interest in radio communication might become even greater than it was if songs and band music were broadcast. The experiment was timidly made. "Did you hear us?" the announcer at the station asked. "Did you like it? Do you want more of it?" The response was overwhelming. In a few months factories were working night and day trying to meet the demand for home radio telephone-receiving sets. Broadcasting stations were established in nearly every large community, chiefly by newspapers, department stores, and radio manufacturers.

Some indication of the radio future thus ushered in is given by the feats of the present day. Already opera is broadcast. Zanzibar, Florida, Minneapolis, and St. Louis will all listen, some day, to Metropolitan Opera. The remotest ranch, the solitary ship at sea, will be present at the first performance of a Broadway theatrical performance; at least so far as the ears

are concerned. Fairy-tales for children? We have them now. The imagination conjures up a radio mother of the future, crooning bedtime songs and telling bedtime stories on a prescribed wave-length to 10,000,000 children who may live anywhere between Alaska and Florida. Education by radio? Its present rudimentary beginnings will be totally eclipsed by lectures delivered to millions of students by the professors of some radio university located in London or New York. Symphony orchestras will play to whole continents, peninsulas, and islands.

Here is an invention that will cause space to shrivel up, that will convert a whole country, even half the planet, into a single huge auditorium. No prediction of radio's future can be so wild, so fantastic, that even the most unimaginative engineer will dismiss it as impossible of realization. Look at a map of the United States and try to conjure up a picture of what home radio will eventually mean. Here are hundreds of little towns set down in type so small that it can hardly be read. How unrelated they seem! Then picture the tens of thousands of farmhouses on the prairies, in the valleys, along the rivers—houses that cannot be noted. It is only an idea that holds them together—the idea that they form part of the United States. One of them might as well be in China and another in Labrador were it not for this binding sense of a common nationality. All these disconnected communities and houses will be united through radio as they were never united by the telegraph and the telephone. The President of the United States delivers important messages in every home, not in cold, impersonal type, but in living speech; he is transformed from what is almost a political abstraction, a personification of the republic's dignity and power, into a kindly father, talking to his children.

The telegraph and the telephone have been called "space annihilators" in their day. Space annihilation indeed! We never really knew what the term meant until the time came when thousands listened at the same time to the voice broadcast through the ether just as if they were all in the same room. Somehow the world seems to contract into a little ball on which Patagonians, Eskimos, Chinese, Americans, Kaffirs, and Apaches are next-door neighbors.

CHAPTER VI

PUTTING SUNLIGHT TO WORK

THE STORY OF THE CAMERA

NOT until the nineteenth century was the first true photograph made, the accomplishment of an unknown young man who earned but never received a place in the Pantheon of Paris, of which edifice he made the first camera picture. Here is the story:

The lens-maker of Paris, Chevalier, stood in his shop one day in the year 1825. A young man, shabby, evidently poor and hungry, entered and timidly asked: "What is the price of your new camera obscura with the convergent meniscus glass?" A meniscus is a lens shaped like a saucer or a watch crystal; one surface curves in, the other curves out. Chevalier named the price, but it was clearly too high for the stranger, who said regretfully: "I have succeeded in fixing the image of the camera obscura on paper." The lens-maker sighed, thinking him yet another fool trying to do what Niepce could not do after long years of experiment. The young man pulled from his pocketbook a piece of paper and laid it on the counter. "That is what I can obtain," he said. Chevalier was amazed. On the paper he saw a view of Paris, sharp as a camera-obscura image, showing the roof and dome of the Pantheon.

The camera obscura had been known to the old Greeks as a dark room, or box, with a hole in it. A ray of light from each point outside came straight through the hole to the opposite side, making an inverted picture of, say, a house across the way. The camera to which the young man referred had been the scientific toy and serious problem of men of science since the sixteenth century, when Porta, an Italian philosopher, popularized it in his book on *Natural Magic*. In his enthusiasm Porta had said: "Now we can discover Nature's greatest secrets." His prediction was to come true.

The young man in Chevalier's shop had fixed that wonderful image which had delighted man for centuries. His picture was a view of Paris as seen from his lodging. The stranger gave Chevalier a flask of fluid, told him how to use it, and left the shop distressed that he could not afford the new camera obscura. Though he had promised to return he was never seen again, and Chevalier, forgetting the directions, lost the precious secret. The unknown inventor of photography had passed by, and his secret with him.

Four things, in order of discovery, were essential to photography: the power of sunlight, the clear image of an object, the plate sensitized to register the image, and chemicals to fix the image.

Miracles of Sunlight

The power of sunlight tans the skin brown—Nature's photography—turns old linen white, fades delicate dyes, and makes modern photography possible. Light is so regular and universal that the magic and wonder of it, which men once worshipped, is unheeded. To-day science revives that reverence, as we learn that the earth came from the sun, that fuel is ancient sunlight, that fossil energy, ages old, heats our homes, runs our mills, drives the peaceful artillery of traffic on roads and steam-railways.

Nature is a sunlit factory where sunshine transmutes water and carbon dioxide into green chlorophyll, the wonderful basis of plant life. Sun-power thus builds plants, whose seeds and fruits feed us, whose fibres (cotton, linen, and the rest) clothe us, and whose wood gives us shelter, furniture, and a myriad useful devices. Sunshine is the color-artist of flowers, fruits, and vegetation, and it becomes the delineator of natural scenes in photography. Doctor Holmes wittily labelled his amateur photo-print: "Taken by Holmes and Sun." Whence the magic power of light? It lies in the rhythmic impact of waves, too small and frequent for conception, trillions of times a second, and shorter than a forty-thousandth of an inch.

All waves carry power. Ocean waves ceaselessly beating the shore, grind rock and shell into fine sand. Rock strata, miles thick, and sandy shores skirting every sea, were built by

wave-power ages ago. Air waves, too, carry power. A powder plant blows up; its air waves strike and break windows miles away. A bugle vibrant with a thousand air waves a second tingles the ear with a note of music. Fanning four strokes a second we feel four separate puffs; a hundred times faster the puffs would be heard, not separately, but as a note, high as a boy's voice. If the fan strokes numbered 400 trillion times a second the ear could not respond, but the eye would see the waves as red light. In the surf we may feel sea waves forty feet long; at the concert we may hear air waves four feet long, a tenor voice; with the eyes we may see waves of red light, each shorter than a forty-thousandth of an inch. The length of the wave varies with the color of light or the pitch of the music.

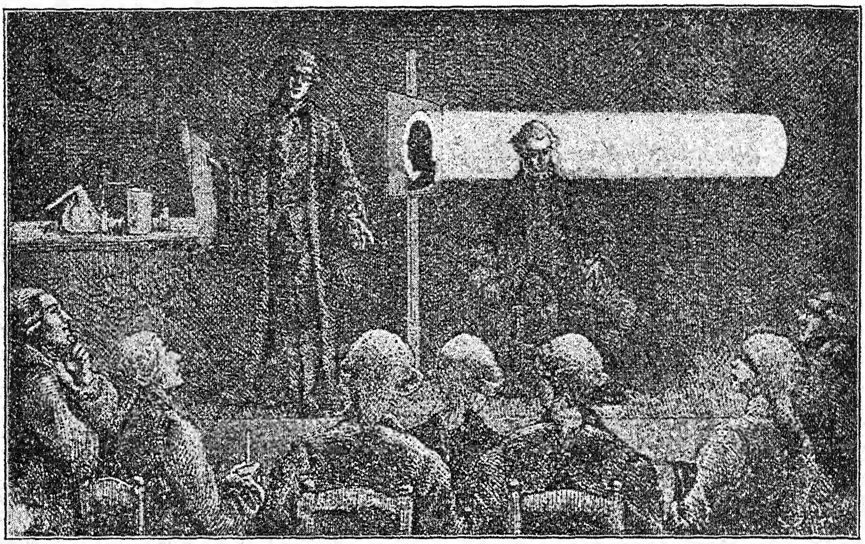
The magic of light waves is unique. Sea waves grind shells, air waves shatter windows, but light waves can break up a molecule of matter. This last is the secret of the photographic power of sunlight, and the first element essential to modern photography.

How Images Are Formed

The next essential is the image. We rarely think of a view as the image in our eye; we regard it as distant. We actually see, however, only what is inside our eye; the picture on the retina. The retina is that wonderful screen in the back of the eye on which is formed the vision of the outside world, instantly perceived by our sense of sight. Eyesight is Nature's instantaneous photography. If we open our eyes the world enters to inform and entertain. Mother Nature gave us twin cameras: our two eyes. Every glance is Nature's photograph in natural color, such a wonderful picture that for ages man did not dream of recording it.

Until we form an image we cannot hope to take a picture of nature. But nature is full of images, made in three ways: by a tiny hole, by a lens, or by a concave mirror. In a darkened room through a keyhole come light rays from a barn; each point sends a ray straight through the keyhole to the wall opposite, forming there an inverted image of the barn. This is the principle of the camera obscura, and in some such way it was discovered. Any aperture is an image-maker; the smaller the

aperture the better defined but the fainter the image. Under the foliage of a tree are many bright spots, each really an inverted picture of the sun. This is very plain in an eclipse, when a myriad crescent suns are pictured on the ground, each formed by a tiny opening in the foliage. The pinhole camera gives remarkable photographs. It needs but a light-tight box with a tiny hole in one side and a sensitive plate in the other.



From Tissandier's "Handbook and History of Photography."

HOW SILHOUETTES WERE MADE BEFORE PHOTOGRAPHY WAS INVENTED.

Lenses also make images. The lens makes a brighter image than the pinhole, for it gathers more light. For centuries the camera image was the wonder and delight of the nature-lover. It was so faint in detail that, about 1550, Cardan, at Nürnberg, decided to enlarge the hole and insert a glass ball. Thus he gave us the first camera lens and a brighter image. Place a white card behind a lens and see the image of the scene in front. Nature is full of such lenses and of images formed by them. Every drop of rain, mist, spray, or dew is a lens, and forms images of all things within sight. The sun thus prints its picture on every dewy leaf or petalled flower. The lens made photography possible with the materials known a cen-

tury ago, and the image has improved only as the lens has been perfected.

Concave mirrors are a third kind of image-maker used, as yet, chiefly in photographing the night sky and the sun. The brilliant scintillations of a rippling lake are countless images of the sun formed by the curved mirrors of the water surface between the ripples.

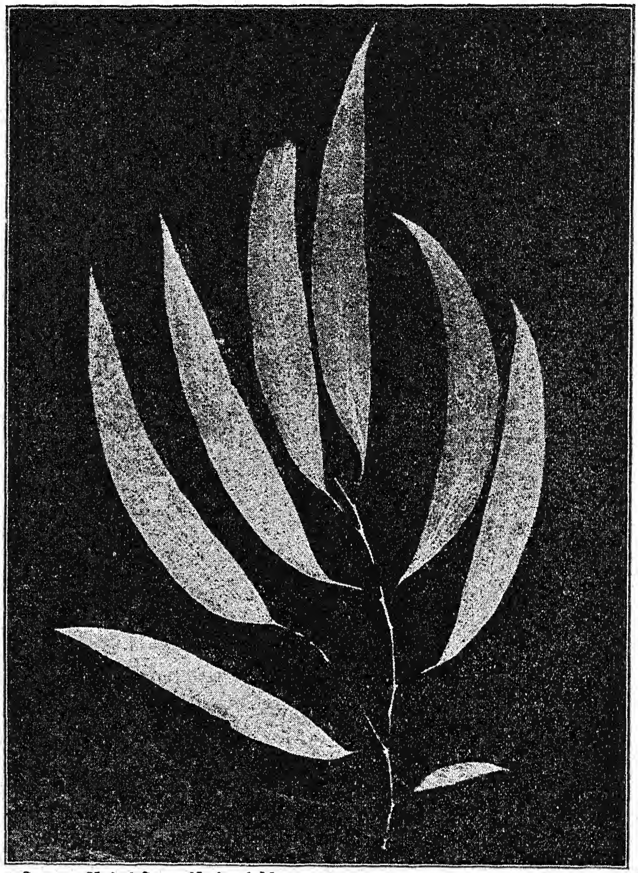
Recording the Image

To hold that beautiful image formed by the camera required a third essential: a sensitized plate to take the impress of the image. The image in the old camera had first awakened admiration, then determination to capture it. Men knew that sunlight changed the color of the skin—darkened it. The effect of sunlight on many substances was also well known to the ancients. The Chinese tradition says that sunlight can photograph nature on a surface of ice. The Greeks knew that opals changed color in sunlight, and Vitruvius placed his paintings in north rooms to preserve their colors. Lacking perhaps the vision or the spirit of experimental adventure the ancients stopped there, and photography waited long centuries for its triumph.

In 1760, Tiphaigne de la Roche, in his wonder book *Giphantie* (anagram of Tiphaigne, the author's name), tells of a magical country where, by means of a prepared canvas coated with a wonderful material, they had succeeded in fixing the image in the mirror. "The mirror," he says, "represents images faithfully, but retains none; our canvas reflects them none the less faithfully, but retains them all. . . . This impression of the image is instantaneous." In imagination the author realized the problem, and foresaw in brilliant fancy the instantaneous photography to be.

In the Middle Ages many wise men studied the dark art of magic and alchemy. Among them, the alchemist Fabricus delved into the ancient lore and sought the alluring secret by which he might transmute the metals, cure diseases, and prolong life. One day in his laboratory he chanced to mix common salt with a solution of nitrate of silver. With astonishment he watched the forming of a milk-white cloud, then saw it turn

black in the sunlight. He studied this wonderful thing. In his *Book of Metals*, printed in 1556, he says that with a lens he made an image on a surface of the white precipitate (now known



Courtesy United States National Museum.

PRINT MADE BY CONTACT OF A LEAF WITH SENSITIZED PAPER.

Leaf-print such as Wedgwood made in 1802.

as silver chloride), and that the image was black or gray according as the image was light or dark. Here Fabricus ends, leaving us expectant. But the serial story had to wait nearly 200 years for its next chapter.

One sunny day in 1727, in Coblitz, Doctor Johann H. Schultze stood by his window, a glass in his hand. The glass

held a curious mixture, silver nitrate solution and powdered chalk. He held it up to the light and the surface promptly turned black. Shaking the mixture created a fresh white surface. He made shadow prints with paper patterns on the liquid surface, reshaking when he wished to produce a new pattern. This astonishing experiment seems to have served the good doctor only to amuse his friends. Photography was in his grasp. He let it slip however, and a hundred more years were yet to pass before the first fixed photograph was made.

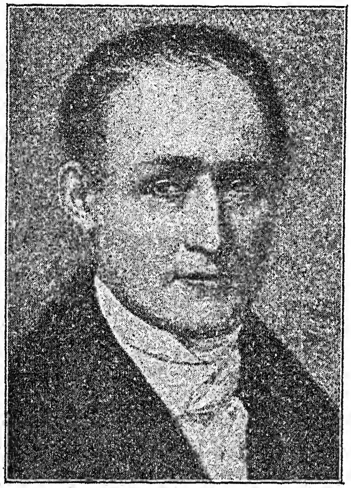
Fifty years later, in 1777, the Swedish chemist, Karl Wilhelm Scheele, proved that blue and violet were chemically many times more effective colors than yellow or red. A wealth of curious bits of information was being gleaned from experiment about this time, but the first use of the process of recording images seems to have been by Professor Jacques Alexandre Charles, the inventor of the hydrogen-gas balloon, and the first to ascend in it. Professor Charles lectured at the Louvre on physics, and, for experimental purposes, about the year 1780, made silhouettes of his students, using silver-salt paper. The shadow protected the salt from darkening. Within a short time the white silhouette also darkened in the light.

Wedgwood and His Contact Prints

The next notable experimenter was Thomas Wedgwood. He was the son of the great English potter and maker of beautiful porcelain, and was one of five children. Three sturdy boys tried the mother's nerves, and the father sent them away to school. There they learned the usual classics, much as the father doubted the wisdom of such studies. Finally his feelings became so strong that he took his sons from school and engaged a tutor. The tutor, of a scientific turn of mind, had been in touch with silver-nitrate experiments for some years, and from him the boys undoubtedly learned much about the sciences and useful arts. Then Thomas Wedgwood went to hear Humphry Davy lecture at the Royal Society, and later began experimenting under his instruction. A brilliant company met during these days at the Wedgwood home: James Watt, inventor of the steam-engine; Thomas Wedgwood's sister who later became the mother of Charles Darwin; Samuel Taylor Coleridge; Joseph

Priestly who discovered oxygen, and Sir Humphry Davy who invented the miner's safety-lamp, and other notables.

Wedgwood's experiments were the making of sun-prints. He placed leaves of plants on paper wet with silver nitrate. In the shadow of the leaf the paper remained white; the exposed paper turned dark in the light. The result was a leaf picture



JOSEPH NICEPHORE NIEPCE.

LOUIS JOSEPH DAGUERRE.

Niepce made the first photographs on tin coated with bitumen of Judea.

Daguerre discovered by accident that mercury vapor could develop a metal plate sensitized with iodine, and thus gave the world the daguerreotype.

in white on a dark background. These pictures were shown only by candle-light, for the same light that created them also destroyed them. He then made pictures on leather, and found they formed faster—almost discovering tannin as a photographic accelerator. After many trials Wedgwood obtained clear images by the solar microscope. About 1802, he announced, with Davy, his success in making such photo-prints (contact prints) on paper, leather, and glass, with exposures of three minutes in sunlight, and several hours in the shade. But, as Humphry Davy wrote at the time: "All that is wanting is a means of preventing the lights of the picture from being afterward colored by daylight." Vainly did Wedgwood seek some chemical, some process, to make the picture image lasting. He

halted on the very threshold of the new art for want of something to dissolve off the unaffected silver salt.

Thus matters stood in 1813, when Niepce began his experiments which resulted in the first fixed photograph. The third essential, the sensitized plate which would take the impress of the image, had been attained. The next step was to discover how to fix the image.

Niepce Fixes the Image

Joseph Nicéphore Niepce was born at Châlons, France, in 1765. A dreamy lad with a poetical turn, he was in no hurry to choose a career. Timid, studious, gentle, industrious, he and his brother played at making machines. With their pocket-knives they cut out devices of wood, cranes, and other appliances. To their delight they worked well. The storm of the Revolution in 1792 swept Nicéphore into the army as a sub-lieutenant. In Sardinia his valor won him a place on his general's staff. Stricken by the epidemic at Nice he was nursed back to health by the devoted and charming Marie Agnes Roméro, whom he later married. Back again in the little home at Châlons he joined his brother in experiment and invention. They perfected many ingenious things. For their work on dyes for military fabric they were liberally rewarded, and for a new type of pump they won a special vote of thanks from the French Academy. They also invented and built a successful motor-boat, and ran it on the Saone River at Châlons.

Printing from stone, so well known to-day, was new to Niepce. Its discovery inspired him to learn the new art. Lacking materials he took some stones intended to repair a near-by road, polished them, and made printing-plates of them. Those stones paved the road to modern photography; for it was his desire to make printing-plates by sunlight that led him to the camera. In 1816 he varnished a piece of tin, placed on it a paper drawing made transparent by varnish, and exposed it to sunlight to study the effect. In the summer of 1817 he sent his brother his first metal prints, saying: "I have not varied my experiments enough to feel beaten. I am by no means discouraged." That year frequent cloudy weather, many visitors, and much visiting hindered him, and—the last straw—he broke

his precious camera-lens. In despair he said: "I would prefer to live in a desert."

But he did not give up. His grandfather's solar microscope made good the lost lens, and he obtained a crude image of a pigeon-house seen from the open window of his workroom. "There are great difficulties," he admitted; "but with work and

By courtesy of National Museum, Washington.

(Left) FIRST PORTRAIT MADE IN AMERICA.

Miss Dorothy Catherine Draper, taken by her brother, Professor John William Draper, M.D., LL.D., of the University of the City of New York, early in 1840.

(Right) COPY OF A PRINT MADE BY NIEPCE.

This was made on tin sensitized with bitumen of Judea, which is soluble in essence of lavender, but which becomes insoluble when exposed to light.

patience one can accomplish much." Indeed his patience was remarkable. Nine more years he labored. Finally, success came from learning the curious out-of-the-way fact that bitumen of Judea, which is soluble in essence of lavender, becomes insoluble when exposed to light.

Coating his tin with the bitumen he exposed it in the camera. He was overjoyed that the lights of the picture became insoluble and white; the rest he washed away with the essence of lavender. After fourteen years of monotonous experimenting

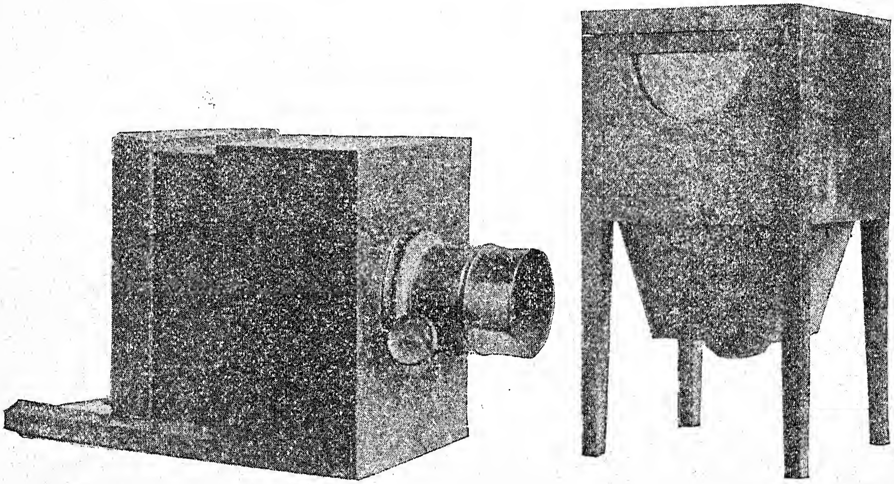
he had, at last, succeeded. His positive was crude, faint, and rudimental; but nevertheless the image was fixed and permanent. Gossips at des Gras, his property near Châlons, had whispered that Niepce was beside himself "working in a vacuum without result"; but success proved him a genius with a great vision. In his crude picture lay the germ of modern photography.

Quietly Niepce had wrested from the unknown the secret of fixing the image of the camera. His other works are lost. His photography remains. It cost him the fortune left him by his father, and twenty years of dreaming and toilsome experiment. Unfortunately he did not live to share the daguerreotype triumph of 1839, but undoubtedly photography had come to the world, about 1827, in the simple country home on the banks of the Saone, and des Gras became the radiant point of one of the most magical of the arts, one of the most versatile of the crafts.

Another Frenchman, Louis Jacques Mandé Daguerre, a revenue officer who became a scene-painter for the Paris theatres, was experimenting along the same lines as Niepce. The lens-maker of Paris, Chevalier, was their mutual friend, and he informed Daguerre that Niepce had "for a very long time occupied himself with reproducing engravings by the action of light on certain chemical agents." Daguerre's first letter to Niepce was thrown into the fire. "Another Parisian trying to pump me," he exclaimed. Their mutual aims, however, at length brought them together in partnership. Many more years were needed to perfect practical photography, for it required seven hours to photograph a landscape, though a monument strongly lit up by the sun could be taken in three.

Meanwhile, in 1837, two years prior to announcements by Daguerre and Fox Talbot, whose discoveries in photography practically coincided with those of the Frenchmen, an English clergyman, Reverend Joseph Bancroft Reade, an amateur astronomer and microscopist, made a contribution to the development of the camera. It came about through his desire to save the expense of a draftsman for his microscopic work. To this end he adopted and began to practise Wedgwood's experiments. On the leather of his wife's light-colored gloves

he photographed a flea, enlarged 150 times in a solar microscope. The exposure was five minutes of sunlight. His wife objected to giving up her second pair of kid gloves. "Then I will tan paper," said Reade. This he did so successfully, with an infusion of nutgalls, that tannin became a developer in modern photography.



Courtesy United States National Museum.

(Left) PORTABLE DAGUERREOTYPE CAMERA USED IN 1851.

One box slides into another for focussing.

(Right) DAGUERREOTYPE DEVELOPING-BOX (1850).

Mercury developing-chamber used in daguerreotype process.

Reade learned from Herschel that hyposulphite of soda, discovered in 1799 by François Chaussier, would dissolve the unchanged silver salt on the exposed plate, and Reade was thus prepared to fix his photograph. Not an ounce of "hypo" could be found in all London, so Reade had a chemist named Hodgson make up some for his experiment. Joseph Bancroft Reade is credited by Sir David Brewster, Captain W. de W. Abney, and the jurors of the Paris Exposition of 1856, with being the first to make a paper negative, to fix the image with "hypo," and to use tannin as a developer. Reade gave his wonderful discoveries to the public as a free gift, holding that "the pleasure of discovery" was "a sufficient reward."

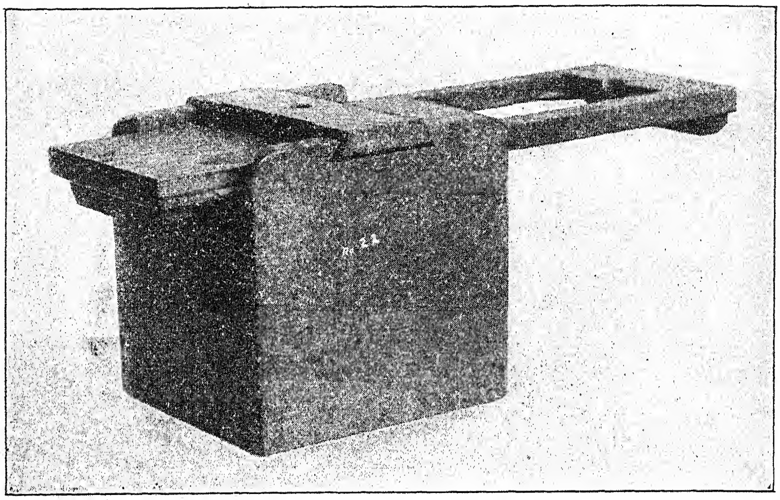
In January, 1839, the same month in which Daguerre announced his success, a wealthy Englishman named Fox Talbot made a similar announcement. The details published the following month, however, showed nothing new in the art. His "photogenic drawing" was much like Wedgwood's of many years before. His "Calotype process" included the use of iodide of silver on a paper support. He also improved the paper negative to permit many copies or positives to be made from it. This was, perhaps, his chief contribution. Talbot admitted his debt to the prior, successful work of Reade; and the latter, in return, credited Talbot with the idea of a latent image. "I threw the ball, and Talbot caught it." said Reade. "It is sufficient reward to me that he publicly acknowledged his obligation, . . ." for "an essential part of his patent." Talbot's patent was later upheld by the court apparently on the slender thread that Reade's admittedly prior work had not been printed, but only publicly described in lectures. Talbot, however, brought the new art before the public, and with his wealth, ingenuity, and persistence did much to establish modern photography by improving the negative.

What a Silver Spoon Taught Daguerre

When Niepce died his son, Isadore, joined Daguerre in experiments which, in 1837, called for capital. Failing in an attempt to start a stock company, Daguerre decided to cede the invention to the French Government for a life pension of 6,000 francs for himself, and 4,000 a year for Isadore.

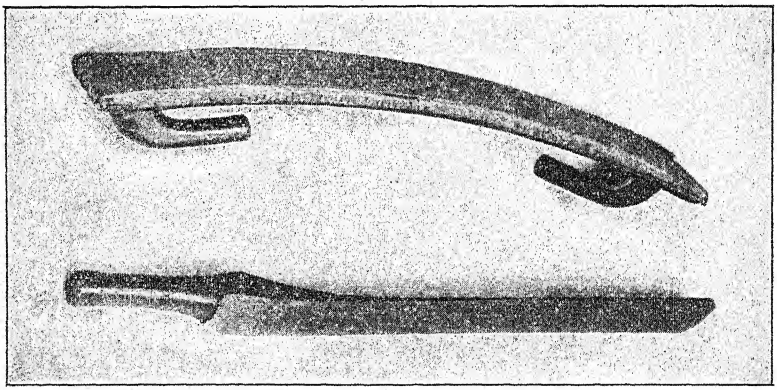
A happy accident started them on the road to final success. One day Daguerre chanced to lay a silver spoon on a metal treated with iodine, and soon found the spoon's image printed on the iodized metal. Hastily polishing a plate of silver he exposed it to iodine vapor, to form silver iodide. A camera image was then impressed on it: a shadowy picture on the plate almost too faint to see. A second, equally fortunate circumstance completed the success. One day he took from his cabinet a plate left by Niepce, and was surprised to find a faint latent image had been developed. Some developer had been at work! His cabinet contained many chemicals; one of them was responsible. He began the search. Each night he put a

fresh plate in the cabinet taking it out in the morning with one of the chemicals. He repeated this until all the chemicals were out of the cabinet, and as luck would have it he placed a fresh



Courtesy United States National Museum.

BOX USED FOR SENSITIZING THE DAGUERREOTYPE PLATE WITH IODINE AND BROMINE.



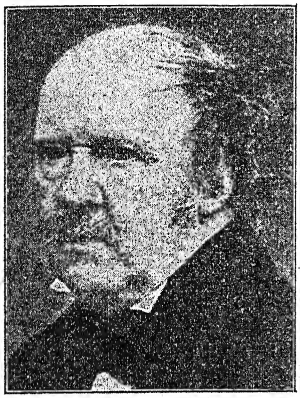
STICKS USED FOR BUFFING DAGUERREOTYPE PLATES BEFORE THEY WERE SENSITIZED.

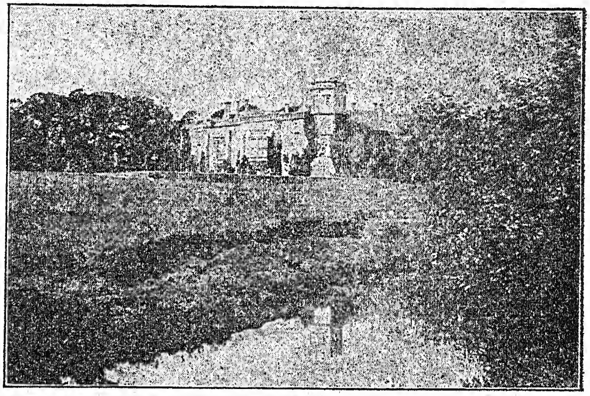
plate in the empty cabinet to make sure of his experiment. To his astonishment he found the plate developed. Examining the cabinet he found some mercury had spilled, and its vapor

had been the developing chemical he was seeking. As we have seen, "hypo" had been suggested by Herschel and used by Reade to remove the unchanged silver salts. By its use, also, Daguerre, after years of determined experiment, obtained the first daguerreotype.

The Triumph of Niepce and Daguerre

The success of Niepce and of Reade had been a triumph of the laboratory. That of Niepce and Daguerre was to be a





Courtesy United States National Museum.

(Left) WILLIAM HENRY FOX TALBOT.

In 1841 he announced the discovery of his calotype or talbotype process. He devised the first process of instantaneous photography after Archer had succeeded in producing collodion.

(Right) LEACOCK ABBEY, FOX TALBOT'S HOME.

From a photograph made by the Talbot process.

public one. If we must fix one moment as the dawn of the art of modern photography, without naming the first discoverer, we may set August 10, 1839; with Paris as the honored city. On that day the French Academy of Fine Arts met with the French Academy of Sciences. Eminent men filled the hall. Daguerre, the scene-painter of Paris, was present, the centre of all eyes. With Paris waiting, and throngs of artists and students in excited crowds packing the approaches to hear the first news of the new art, Arago announced that Niepce and Daguerre had successfully produced a permanent photograph. Nature had printed her image on silver! Paris, and later the

world, buzzed with excitement. Delaroche enthusiastically begged a plate from Daguerre, and showed it everywhere. "From this day the art of painting is dead," he exclaimed. Delaroche was wrong. Instead of superseding painting, the camera was to sustain and advance it.

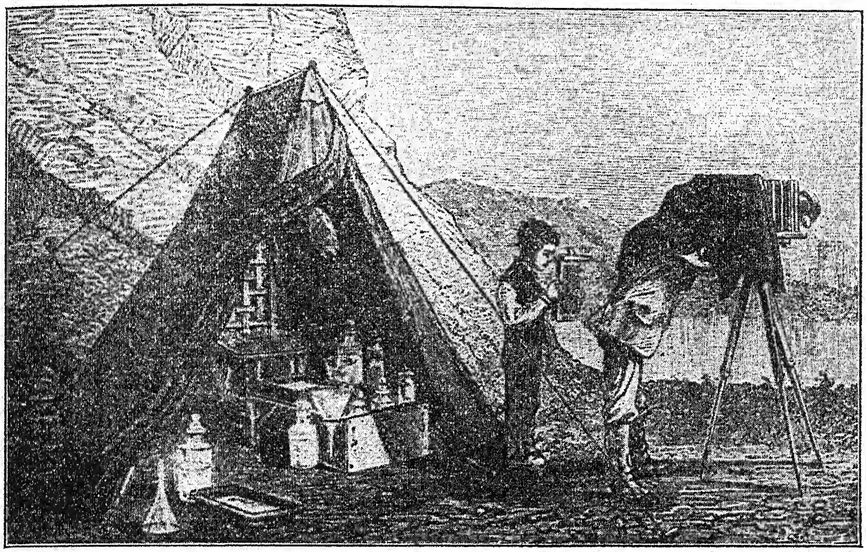
The world seemed to awaken at once to the possibilities of photography. Opticians began experimenting; lenses and cameras were exhibited in shop windows; modern photography had arrived. The history of invention here records a rare happening. As already told, France pensioned the inventors, and secured the precious secret. She also gave it a free gift, not her first, to the fine arts of the world.

Among the interested experimenters of the time was M. Bayard, bureau chief of the Ministry of Marine. Some weeks before Arago announced Daguerre's process, Bayard gave an exhibition in the studio of Comte O. Aguado, making a positive proof on paper, direct in the camera. He first placed a prepared plate in the camera, and to the chagrin of his aids, who knew the plate was blackened, he pretended to inspect it by opening wide the camera door, exposing the plate to daylight. "Bah!" he said, "it's all the same." Hastily putting some iodide of potassium over the exposed plate, he put it back in the camera. To the surprise of every one, except Bayard, the resulting photograph was a positive made direct in the camera by over-exposure. This extraordinary fact may yet assume importance when the quest for instantaneous direct positive photography becomes more insistent.

America Begins to Photograph

In 1839, the year of publicity, the news of the discovery of photography crossed the Atlantic. To America came the London *Literary Gazette* with word of Daguerre's success. The effect was electric. Within two or three days successful photographs were made by Draper, Morse, and Wolcott, separately. Professor John William Draper was a doctor of medicine, professor at the University of New York, and an author of note. He at once bought supplies, and, by the Daguerre method, photographed a church. Soon afterward, he made a "sunprint" of his daughter, Dorothy Catherine, using a five-inch lens of

seven-inch focus, and setting the focus sharp for the violet ray; for achromatic or non-color lenses were still unknown. So that under a brilliant New York sun was the first human portrait taken by Professor Draper. So lightly was portraiture then regarded that the French reports do not mention Draper's work at all. Meanwhile, Samuel F. B. Morse, the inventor-to-be of



From Tissandier's "History and Handbook of Photography."

A WET-PLATE PHOTOGRAPHER AT WORK IN THE FIELD.

the telegraph, successfully photographed his daughter, and later charged sitters for portraits in order to make money to resume his work on the invention of the electric telegraph. About the same time, in the first week of the new art, Alexander S. Wolcott, also of New York, produced a portrait using a reflector eight inches across, with a twelve-inch focus, instead of a lens.

Daguerre refused to have his portrait taken by the process he invented, until one day a persistent American secured the support of Daguerre's family, and together they induced him to make one sitting, the only picture he ever permitted.

Daguerreotypes became common; but the sittings were so tiresome, the conditions so bad, the plates so slow, that it was not easy to find any one willing to sit for a portrait, or pay

twenty shillings for a poor likeness. The result was, at best, "a ghostly thing—a shimmering phantom." Our poor forefathers had to pose out-of-doors for an exposure of twenty minutes' duration, and the torture of their immobility under the dazzling rays of the sun is a quaint and amusing characteristic of the early daguerreotypes. Indeed, so slow was the performance that a photographer making his own portrait had ample time to remove the lens cap, leisurely take his seat, pose himself, rise in about twenty minutes, and go to the camera to replace the cap—all without disfiguring the picture. To register the eyes faithfully seemed difficult, and early portraits show the "sitters" with their eyes closed. The face was generally powdered with flour. In fact the failure of the new art was averted only by later improvements. About this time, H. L. Fizeau devised a means of gilding the image and making it more permanent. But photography would not have succeeded had it not been possible to obtain good results in a moderated light.

Further improvement came in two ways. Professor Petzval, of Vienna, "speeded up" the plate by perfecting a camera-lens which made a sharp image with good light-gathering power. In 1840, Professor John F. Goddard, then lecturer in science at the Adelaide Gallery in London, cut the exposure time from twenty minutes to twenty seconds at one stroke by the use of bromine in place of iodine; thus making bromines an institution and photography an assured art. Professor Goddard also invented the polariscope, and with characteristic generosity freely gave his secrets to the world. Later, when he suffered distressing poverty, his friends, and the friends of his art, willingly made up and subscribed to a fund ample for his old age, and they coupled the gift with appreciation worth, perhaps, more than the annuity.

In 1843, Mungo Ponton gave a new turn to photographic processes. He found that in an alkaline bichromate of potash solution, gelatine became insoluble when the mixture was exposed to light. The shielded parts were dissolved off, thus leaving the picture clear; an excellent process for making paper positives, and the basis of modern "process" engraving. After Ponton's work, Poitevin, in 1855, invented a new process based on the bichromate idea. After exposing the gelatine-coated

paper containing the bichromate of potash, the paper was bathed in hot water to dissolve the gelatine untouched by light. The lights of the image made the gelatine insoluble. Mix finely powdered carbon, or any other colored pigment, with the gelatine, and carbon photo-prints and other mono-color prints are possible. Sir John Herschel, about 1839, gave us the "cyanotype," or the now world-wide art of the "blue print"; the modern link between the engineer and finished project, the designer and the finished machine.

The Invention of the Collodion Process

In the year 1847 there lived in Switzerland, in the town of Basle, two chemists, Schönbein and Böttcher. Dipping cotton into nitric and sulphuric acids they made a new explosive, "guncotton," soluble in ether and alcohol. This solution was, and still is, used on cuts and burns. We call it "collodion," meaning adhesive. A London sculptor, Frederick S. Archer, admired this delicate film and sought to sensitize it for use in his camera. For a time he spent his leisure and money in vain, until, one day, he tried mixing his sensitizing material direct in the liquid before pouring it on the film. Success was instant and complete. The collodion process leaped into popularity everywhere, and Archer's service to the world was immeasurable, for a great industry and art resulted. In 1851, in the March issue of *The Chemist*, he gave his priceless secret to the world without patent or reward. Useful as his process was, he died poor, leaving his wife and three children destitute. The London *Punch*, in its issue of June 13, 1857, made a witty appeal for aid. In camera phraseology, *Punch* said: "A deposit of silver is wanted (gold will do), and certain faces, now in the dark chamber, will light up wonderfully, with an effect never before equalled in photography. . . . Answers must not be negatives." A quick response brought ample means; the Queen herself approving a private pension of fifty pounds sterling a year. The collodion wet-plate process is so suited to color photography and color printing processes that its use is still popular, although in general the dry plate has superseded it.

During the siege of 1870, Paris was cut off from the world. M. Dagron called the camera to the rescue, borrowed a Chinese

invention, carrier pigeons, and organized the famous "pigeon post." French cameras photographed news and personal despatches to such small size that a single pigeon carried 50,000 messages, which together weighed less than a gram. The collodion negative was stripped from the plate, rolled into a small quill, affixed to the wing, and the bird with its precious message released. Flocks sent out of Paris in balloons flew back with similarly concealed messages. At the destination the film rolls were carefully removed from the quill, put in water to unroll, then placed between two plates of glass and enlarged on the screen by magic-lantern, while clerks copied the messages. More than two and a half million despatches were sent in this way. One of the picturesque memories of Paris siege days is that of the gendarmes opening large baskets and setting free pigeons, each bird carrying thousands of despatches made by the camera.

Taupenot and the First Dry Plate

The wet-plate process was clumsy for field-work. A "portable" outfit was a formidable affair, with its tents, tools, dishes, bottles, apparatus, and solutions, a veritable "push-cart" process, so that, in 1855, it had been hailed as a happy event when Taupenot, a Frenchman, produced the first "dry plate" by coating glass with collodion and albumen. Eleven years later Hill Norris made an improvement by coating collodion plates with gelatine dissolved in water and alcohol, developing with gallic acid and nitrate of silver.

Then came a great step forward. In 1871, Richard L. Maddox, a physician of Woolston, England, used gelatine in place of collodion, and bromine in place of iodine. His method —the "gelatino-bromide dry-plate process"—is in use to-day, the basis of modern photography. The great feature was the use of a sensitized emulsion which could be poured on the plate and dried.

About 1878 a bank clerk in Rochester, New York, was an interested amateur. It took enthusiasm to become an amateur with clumsy wet plates. But George Eastman's vision foresaw that photography might grow into a huge business. Fitting up a little shop he conducted many experiments,

after hours. Gelatine and silver bromide plates were then being tried in America and abroad. John Carbutt of Philadelphia had introduced the use of coated, celluloid cut film, and Eastman's experiments led him to the making and selling of dry plates.

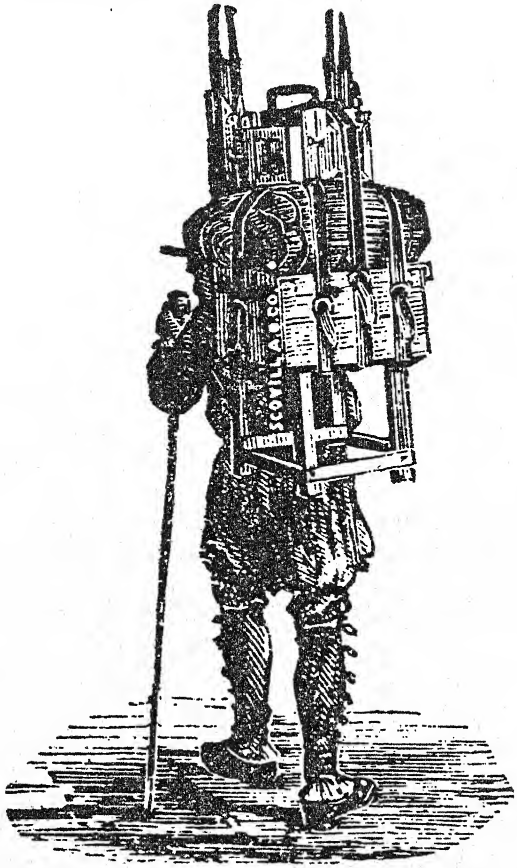
Goodwin, Eastman, and the Modern Roll-Film Camera

A new era was on. Glass plates, heavy, bulky, expensive, and brittle, were still used. Could Eastman replace them with something better? Eastman tried paper, but the fibres showed when greased—a process necessary to obtain a negative. He tried a film of gelatine, to be stripped off like a skin. The film was transparent enough, but hard to manage. Success came at last by using celluloid, the process for which (unknown to Eastman) had been patented by Hannibal Goodwin in 1887. Lines had been laid down which were to make the camera a plaything for the world's leisure, and a wonderful tool for its serious work. Eastman named his film camera the "kodak," and by his enterprise gave the word a meaning no child would mistake, and made it, perhaps, the best-known coined word in the world.

The kodak—a box with a roll shutter—was portable and easy to manage. Its instantaneous shutter was at first operated by a string. The films were perforated; the exposures were numbered; the container could be removed to insert new film. It was, in effect, the modern film camera, crude as Eastman later regarded it. The motto, "You press the button, we do the rest," made the kodak a veritable genius of the lamp, and each kodak-owner an Aladdin of pictures. Possessing a kodak, any amateur could make a fadeless picture of New York Harbor, for example, with a fidelity no artist could equal in a lifetime of work. This great achievement, making the new art accessible to all, is largely to be ascribed to the enterprise of George Eastman.

Hannibal Goodwin was a clergyman in Newark, New Jersey. In 1887 he devised a process for making celluloid film, which he demonstrated to the industry. He filed a patent application, but this was not issued until a later and conflicting application had been filed and, on appeal, granted. As for

Goodwin's patent, although it had been applied for first, it was not granted until his funds, and those of his friends, were exhausted. A bitter legal fight was waged in the district court for more than ten years, the courts eventually confirming the prior right of Goodwin.



From Tissandier's "History and Handbook of Photography."

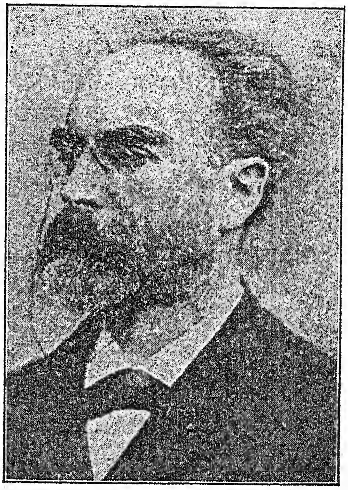
THE AMATEUR TRAVELLING EQUIPMENT IN PRE-KODAK DAYS.

Explosive gun-cotton turns to peaceful uses quite naturally, and combines with camphor to produce the photographic film. It is a big industry. The Eastman Company alone could girdle the earth in a month with film; it uses every week forty tons of gun-cotton and three of pure silver (a twelfth of all our new native silver). Cotton, treated with nitric and sul-

phuric acids, becomes soluble in wood alcohol. Washed and churned, it forms a syrup-like preparation which is then formed into sheets, two-hundredths of an inch thick, thirty inches wide, and 2,000 feet long. Dried and coated with sensitizing chemicals, its thickness is controlled so nicely that it does not vary one eight-thousandth inch. In the dust-free atmosphere of a

GEORGE EASTMAN.

Inventor of the modern portable roll-film camera.



GABRIEL LIPPMAN.

He helped to lay the foundations of color photography.

wonderful laboratory equipped for the complete control of indoor climate, and with light which permits visibility without fogging the film, this enormous industry flourishes and provides a story full of interest and adventure. Here researches are made on the behavior of chemicals under the action of light, so as to make photography a pastime for any boy, and perfect the motion-picture film to be the world's greatest instructor and entertainer.

Giving Eyes to the Camera

A lens is supposed to be needed to form an image; but a pinhole suffices, and beautiful pictures have been made by home-made pinhole cameras. With a given pinhole, images of varying size can be formed. Focussing is not required and the

picture is not distorted at the margins. Equal definition all over the plate is obtained for the same hole-to-plate distance, so the swing-back can be used for architecture. The pinhole gives equal separation or expression of detail all over the picture. There is no critical sharpness, however, and there may be no moving figures in the view. A long exposure is required, so that instantaneous photography would be out of the question. The lens in the aperture, however, has made the image bright enough and sharp enough to affect the chemicals and give us the modern photograph. As explained at the beginning of this chapter, for centuries the aperture of the camera was open, until, in 1550, Cardan enlarged the hole and inserted a glass ball, giving us the first camera-lens. It was not very successful, but experiment following experiment the modern high-speed camera-lens was the result.

The lens is the silent partner of the sensitized plate. Curved by the grinder, a piece of glass enforces nature to record her image on the camera-plate and thus make photography possible. It seems easy to bring a beam of light to a focus; with a burning-glass, for example. Seen closer, however, such a focus is not a fine sharp point of white light, but a colored, hazy spot. Why? White light is a mixture of colors; each comes to a focus at a different distance. Blue rays bend easily in a lens and focus nearer than red. If the blue is focussed to a sharp point the other colors not in focus form circles around the point of blue. This blurs the image in an ordinary lens. The story of making a lens giving an uncolored focus of white light would fill an entertaining volume. The bending power of a given glass depends on its shape; the more curved the greater the bending. Complex lenses correct the excess bending of the blue and the too slight bending of the red, so as to focus all colors at the same distance; that is, at the plate. Such a lens is "achromatic"; meaning, without color. The production of such a lens was one of the first steps toward modern photography.

But a camera-lens must have more wizardry. A landscape has three dimensions in nature; the camera-lens must reduce it to two. A pinhole camera has no focus; hence the picture may be formed at any distance. A far tree focusses nearer an ordinary lens than a near tree, and the designer must so design his

lens for near and far sight that all trees focus sharp at the same distance from the lens. But the modern short-focus lens almost succeeds. It has "depth." Lens magic compresses Nature's third dimension—distance—to zero.

A third thing a lens must do. Each point of a lens receives from every point of a scene a ray of light, and in turn must send a ray to every point of the picture. Countless ray cones thus interlace in almost infinite complexity. Lens magic must disentangle this to weave the beautiful image on the camera plate. To do so without distortion, making a sharp, clear image in true colors only, without unduly blurring near and far objects, is surely a fascinating possibility of lens magic.

A good lens demands the utmost in computation from the designer. One such camera lens—the Goerz—is said to have cost years of labor of several experts, and many thousands of dollars, simply to design and produce the first model lens. To shape the lens thus computed is a triumph of the glass-worker's skill; the craftsman can grind a lens true to plan with no error as great as a half-millionth part of an inch. We may yet improve the lens; but it is, to-day, a masterpiece, gifted with remarkable powers.

Curing the Camera's Color Blindness

The camera was born color blind; it recorded only blue and violet, and these only as tints of gray. What a drab world it would be without the gaiety of colors, and yet that was the world photography gave us. It hardly responded to green, and not at all to yellow, orange, or red light, which three might well have been black. For half a century this seemed incurable. Blue sky showed white, the red schoolhouse and the yellow sunflower both showed black in the picture. By spectacles we correct the lens of the human eye for defective curvature, but so far we have failed to cure its color blindness.

How then could we cure the color-blind camera plate? Happily the camera has a detachable "retina," whose sensitiveness depends not on physiology but on chemistry. The task was one for the chemists. They did not fail us. The way out came most unexpectedly. While Doctor Vogel was experimenting in 1873, trying to stop the spreading of light on his plate

during exposure, he found to his astonishment and delight that the plate, which he had bathed in aniline red, had actually registered the greens. With quick insight he saw that the camera's color blindness might be curable, and that he had accidentally stumbled on the remedy.

A big discovery lay wrapped up in the fascinating riddle. How could aniline red make his plate sensitive to green? The answer gave the clue to success. Red and green—complementary colors—together make white, or at least light gray. Take red from white, green remains; take green from white, red is left. A rose is red in white light because it reflects only the red part of the light. What becomes of the green? The green is absorbed, digested, feeding energy to the rose. A green leaf, however, reflects green, absorbs red. So when Vogel's plate dipped in red dye absorbed the green rays, the plate became sensitive to the color absorbed, not to the color reflected. He was justly thrilled with the idea of making plates sensitive to any color. To master the method was not easy, for the "optical sensitizing" of the plate, as we now call it, was then virgin soil.

The road thus opened wide by Vogel led to success thirty years later, but in 1873, only one in six of his plates worked well. Gelatine gave even more trouble. Tinting collodion dulled it for other useful rays and made it too slow. The discouraging results were ridiculed by the British *Journal of Photography*, but failure was not to be thought of.

Two years later, an English army officer, Colonel Waterhouse, found that eosine dye sensitized the plate for yellow-green. In France, Becquerel found that chlorophyll, the green colorant in plants, made plates respond to orange-red. This was indeed progress. The camera now responded to all colors but red.

Hot on the trail, Vogel, Schumann, Eder, and others tried out hundreds of dyes. A few proved useful, and these pointed the way. Erythrosin is still used to make plates sensitive to yellow-green, for landscape and similar work. It was far too soon to name the new plates "orthochromatic," or "right-color" —meaning that the resulting tints of gray varied true with the brightness of the colors in the scene—for the plates were still unresponsive to red. Only in 1904, when König discovered pinacyanol, was a nearly "panchromatic," or all color-plate made.

With it came pinachrome and orthochrome "T" dyes. These were too fugitive for dyeing fabric, but this very fault became a prized virtue in sensitizing camera plates to certain colors. Bathing a plate ten minutes in ammonia water and alcohol with a millionth part, by weight, of pinacyanol—an astonishingly small quantity—the plate becomes sensitive to green, yellow, orange, and red, and incidentally needs but one-fourth the exposure time.

The experimenters were now well on the way to give the camera the same color sense as the eye. But the blues were still too active; deep blue showed white, bright red was dark. Here a simple bit of common sense solved the problem. A yellow screen in front of the lens cut out some of the blue; an obvious, easy, and successful device. This meant longer exposure, for blue prints quickly, and to screen out any of the blue slowed down the process. Screens may call for four times the usual exposure, but the result is worth while. Panchromatic plates are slower; their one defect. The battle-fleet is only as fast as the slowest moving ship; so the panchromatic plate is only as fast as the slowest registering color: red. Dicyanin, a rare blue dye, was later found to be sensitive to the longer red rays. By manipulation, worked out at the Bureau of Standards, Washington, in war time, was photographed through haze or light clouds by using only the redder rays of the scene, the haze blue being absorbed by the screen. Clear pictures were taken "through the clouds" at heights of nearly two miles with an exposure of only a hundredth of a second.

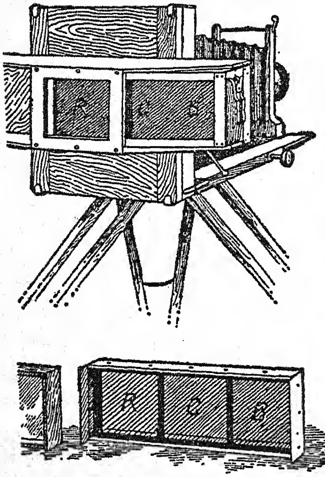
Thus far photography has meant producing gray lights and shades corresponding in brightness to the brightness of the colors of the original scene. To produce a photograph in natural colors, however, was a dream long before simple photography was achieved, for the charm of the old camera obscura image was its natural color.

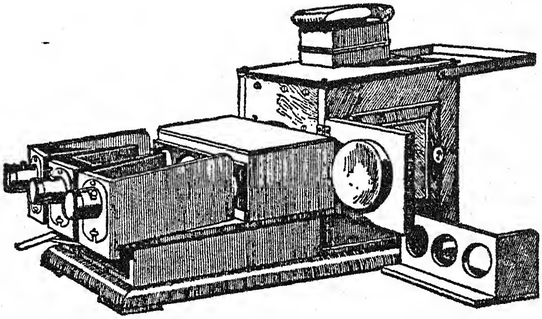
And Now Photography in Natural Colors

In Goethe's *Farbenlehre* (Treatise on Color) of 1810, Thomas Johann Seebeck tells of a color spectrum he exposed to moist chloride of silver paper and how, after about twenty minutes, he observed the sensitized paper take on all the colors of the

spectrum falling upon it. J. M. Eder names this the first record of natural color photography. It is appropriate that it should be the spectrum; that natural and visible gamut of colors in the sequence of their natural wave-lengths or frequencies.

In 1840 John Herschel successfully repeated Seebeck's experiment. In 1847 Edmond Becquerel made impressions in color on silver coated with subchloride of silver, heating it in





From "Kromskop Color Photography," by Fred. Ives.

(Left) MULTIPLE BACK KROMSKOP CAMERA OF IVES.

The letters "R," "G," "B" stand for "red," "green," and "blue." Three negatives were made, each registering only its own color.

(Right) THE IVES LANTERN KROMSKOP.

The red, green, and blue images were projected on the screen, and these blended into a single perfect reproduction in natural colors of the object photographed.

the dark, exposing it in the solar spectrum, and obtaining the colors. He thus photographed in full color drawings and objects as well as the spectrum. They vanished in daylight, but some specimens, preserved in the dark since 1850, were said to be still perceptible as late as 1912.

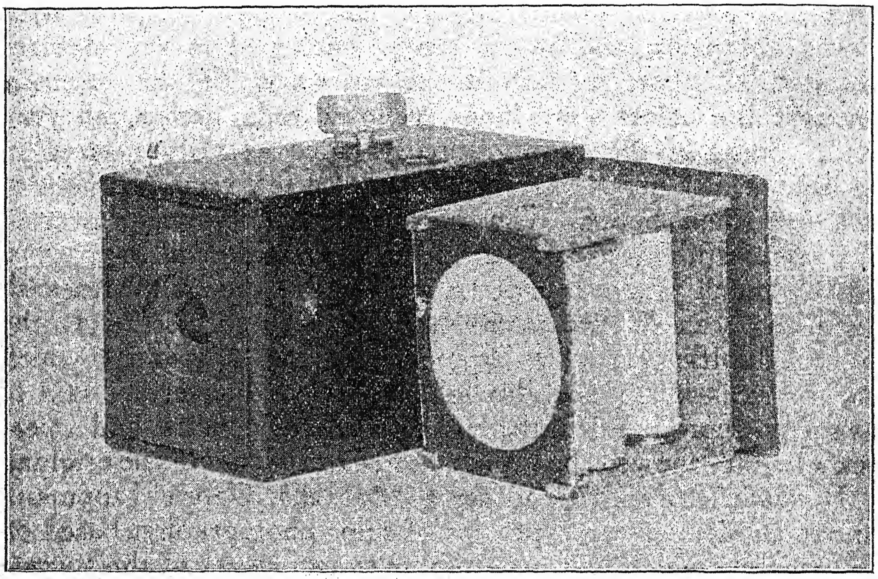
Niepce de Saint Victor, the nephew of Niepce, was a clever and ardent student of photography, especially of color photography. He was lieutenant in the municipal guard at Paris. At his quarters in Saint-Martin he made a work-table of his camp-bed, using the shelves for chemicals and apparatus. The police-room was his laboratory. By day he experimented, at

night with helmet and sword he guarded the city. The quarters were burned in the Revolution of 1848, but he pursued his work on color plates until he succeeded not only with the reds, blues, and greens, but at last with the yellows. These he recorded in very beautiful color photographs on a single plate, but the pictures made by Niepce de Saint Victor were not permanent. The jury of the 1862 International Exhibition examined and reported upon a dozen of his color photographs, about three and one-half inches by two and one-half, figures with colored draperies, and stated that, "each tint in the pictures exhibited . . . was a faithful reproduction of the original. Amongst the colors were blues, yellows, reds, greens, all very vivid. Some of the tints gradually faded and disappeared in the light whilst under examination, and a few remained permanent for some hours. The possibility of producing natural color thus established is a fact most interesting and important, and too much praise cannot be awarded to the skilful research which has been to this extent crowned with success." At the Paris Exhibition of 1867 Niepce exhibited specimens which lasted a week in diffused daylight. Gold and silver are said to have been reproduced in their natural metallic lustre, and a peacock's feather showed the brilliant tints and shades of the original.

It was in Paris, on February 2, 1891, that Gabriel Lippmann announced his perfected process of color photography, based on the principle which had been the unknown secret of the success of Seebeck, Herschel, Becquerel, and Niepce de Saint Victor. Zenker and Rood are credited with the true explanation of their results. Lippmann's process gave us such magical permanent color photographs, without colorants of any kind or color screens, that its interesting principle is worth understanding. A simple illustration will assist.

If an incoming wave strikes a vertical sea-wall the wave is reflected back to the sea. Its crest meets the incoming crest of the next wave at a certain distance from the sea-wall. The distance depends on the interval between waves. Coming regularly forty feet apart, the reflected crest meets the incoming crest twenty feet, let us say, from the sea-wall. Crest meeting crest, doubles the wave intensity at this point. An instant later, at the same place, trough joins trough, extending their

spread. At ten feet from the sea-wall, however, the outgoing crest meets the incoming trough and cancels it, and an instant later the incoming crest cancels the outgoing trough, thereby forming a calm region. The effect, called "interference," gives us "standing waves." This is, perhaps, clearer if we pluck regularly at a tightly stretched clothes-line. We see the wave run to the post at the other end and, reflected back, meeting the



THE FIRST EASTMAN KODAK (1888).

This kodak took round pictures, two and one-half inches in diameter, and was loaded at the factory for one hundred exposures.

later arriving crests at definite distances, one wave-length apart. We then see a series of vibrating sections—standing waves—between fixed points of rest along the rope. Something like this occurs in the Lippmann film principle.

Suppose we place a sensitized film on a polished metal mirror, and on it photograph a yellow spot. What occurs? A wave of yellow light passes through the film and is reflected back. The crest of the wave meets the crest of the next incoming wave at a certain distance from the mirror. Crest meeting crest, the wave action at this point is more intense. Crests

would meet a half wave-length from the plate if the light were not delayed at the mirror surface (actually, it is delayed). In the film, however, at regular intervals, one wave-length apart, are a score or more layers of intense wave action, separated by layers of calm, and these alternate layers have fixed positions. The silver salts in the active layer are darkened, but not in the calm layers.

The developed plate of our photograph will now reflect only the yellow part of a white-light beam, for the score of layers just a yellow-light wave apart act to select and reflect the color which made them. Other colors act in the same way. Each color makes layers separated by a distance equal to its own wave-length. With care beautiful color photographs are possible by the Lippmann process, which naturally has its limitations.

Curious as it seems, color printing is easier than color photography. Printing uses three plates, and the three colors blend on the paper to form the others needed. This "three-color" process of printing suggested "three-color photography"; it was thought that three gray negatives, one for each primary color, with three-color screens to match, could be used to give the effect of natural colors. Viewing any illustration in color, with a lens, you see three colors; and sometimes black is added. How this really wonderful effect is produced is as simple as it is interesting.

Scientists, in studying color, found that the endless variety of color sensation is caused by three primary color sensations arising from the nerve structure and action of the eye. The primary color sensations are really violet, green, and orange-red, although in three-color printing excellent results are obtained with the supposedly three primary colors, red, yellow, and blue.

If we photograph through a screen which lets only red pass, we record in grays, darker as the red light is brighter. So for yellow and blue, the grays give in reverse the brightness of these colors. Three printing plates, one from each negative, are used to print in the colors of the three screens used in taking the pictures. On the print paper the colors superpose and mix in the eye to reproduce the colors of the original. It is hard to realize that we need but three colors, at most four, to give all the natural colors of an original scene.

Using the three-color idea, Frederick Ives, of Philadelphia, made a very striking invention, applying also the binocular effect. He made three gray transparencies, using three appropriate color screens, and in an ingenious apparatus he combined the three pictures by a system of lights and mirrors. He thus gave to the observer not only the colors of the original by synthesis, but, by a pair of each element, he gave a stereoscopic or solid effect to the view. More precisely than concisely Ives named his device the "stereophotochromoscope."

In 1897, Professor Joly, of Dublin, introduced a color process by which three sets of colored lines were ruled on a plate, close together, and colored alternately red, green, blue. Thus he had three color screens on one plate. A sensitized plate, back of such a screen, took a composite gray picture recording in all parts of the plate the intensities of each of the three colors. Under the red lines of the screen the grays recorded in reverse the red elements, and so on with the other colors. By contact a copy was made in which the brightness corresponds with that of the original. Viewing the resulting picture, when developed, through a similarly ruled screen—but one having the natural visual primaries, matched line for line—the original colors appeared by the blending of the three elementary colors.

Messrs A. Lumière and Sons in 1907 made a brilliant application of the composite trichromatic screen principle in a most novel process. They used tiny balls of starch, clear, and so minute that the naked eye could not distinguish them. They dyed some of them red, others green, the rest blue, mixing all until they appeared gray. They then spread the colored starch grains on the plate. Only twenty-six per cent of the grains were blue, for blue photographs inordinately well; thirty-eight per cent were dyed red, for red photographs slowly. Thus did the Lumières correct for the unequal photographing power of these colors, and the process, called the Lumière autochrome, produced beautiful plates.

The principle involved is interesting. Each red grain is a tiny color screen under which forms a spot of dark gray, dark in proportion to the brightness of the red element of the scene at that point. Likewise for the yellow and blue grains. After development, but before fixing, the darkened silver under each

grain is dissolved. The unchanged silver left in each spot is then darkened and the plate is fixed. Seen through the same colored grains with which it was taken, the picture shows the true colors of the original scene, each color now having its intensity at all points determined by the transparency of the gray under each colored grain.

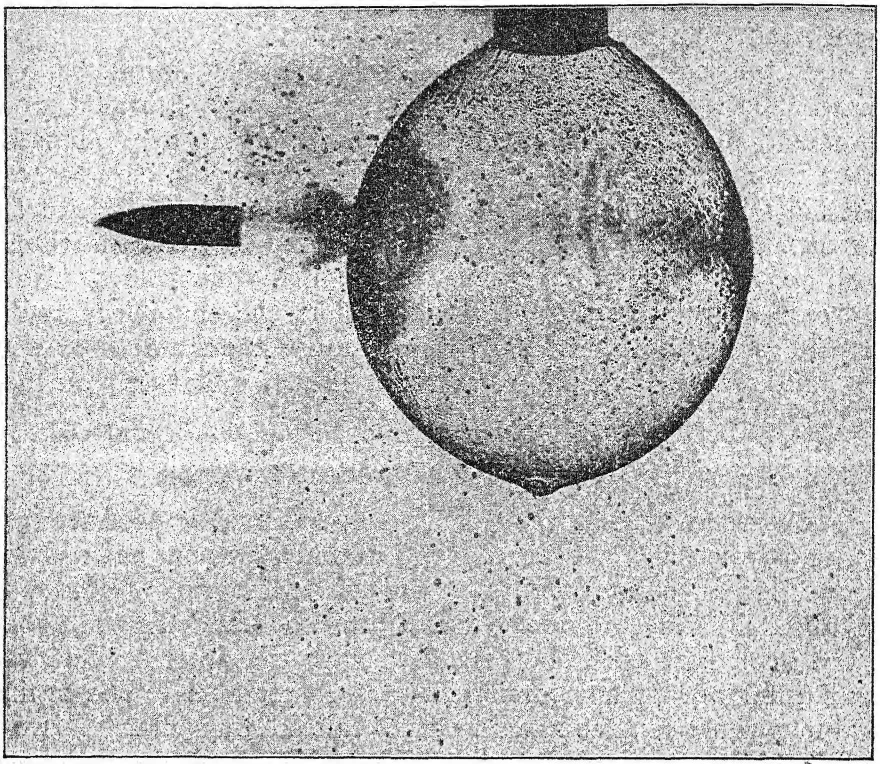
Such photographs are viewed, like stained-glass windows, by transmitted light. Wonderful as is the work of Gabriel Lippmann and the Lumières, inventors are still trying to produce a direct true photograph in natural color. Perhaps a three-color makeshift is the most we may expect in the immediate future. Our own eye vision, in fact, consists of three-colored sensations combined in varying proportions to produce other colors. But to create a sensitive molecule, which, like the chameleon, will turn the hue of the incident light, but unlike the chameleon, will hold that color—that is the alluring dream and task for the photochemist of to-morrow.

Giving the Camera Binocular Vision

The camera was born with one eye; hence it produced a flat, one-eye view. Perspective and dimmed outlines gave some effect of distance, but solidity, or the third dimension (distance), was absent. Place a finger between this book and the eye, look at the book first with one eye, then with the other. The two views differ but do not conflict when seen together. The brain combines them to give a solid effect, called "binocular," "two-eyed," or "stereoscopic" (solid-seeing) vision. By it we judge distance and solid form.

Euclid, in 300 B. C., defined stereoscopic vision. But it was not until 1838 that Wheatstone gave us the first stereoscopic device, which, with twin mirrors, picture-holders, and eye-pieces, permitted seeing at the same time both right-eyed and left-eyed pictures of an object. These gave the effect of relief. Early cameras with two lenses for taking such double (two-eyed) views were invented very early. A similar effect is obtained by double pictures (two exposures), to accomplish which the camera is moved a few inches to one side; that is, the distance from the pupil of one eye to the pupil of the other. The camera first photographs the scene as viewed by one eye,

and secondly as viewed by the other. Seeing these together through a stereoscope, the effect is one of solid relief. If we can take two exposures a few inches apart, we can do so with exposures many feet apart. One such view of Blackwell's Island



Photograph by Phillip P. Quale.

A BULLET PIERCING A SOAP-BUBBLE.

The exposure time was of the order of 0.000001 second. The bullet, an American spitzer, 30 caliber, had a speed of 2,700 feet per second. The spatter in the background is due to the soap solution flung out when the collapse initiated by the piercing of the bubble by the projectile was completed. The photograph shows clearly that the collapse of the soap-bubble is a slow process compared with the speed of the projectile.

has been photographed from an East River bridge with two exposures spaced thirty feet apart, and towns have been snapped a mile or two up in the air at intervals of half a mile. Such views give powerful solid effect as of models on a table. Quite remarkable effects are obtained by such twin photographs in astronomy. The moon wobbles slightly and does not always

present exactly the same face, so we can photograph the moon at each extreme of the swing and secure vivid stereoscopic effects on the lunar mountains. In this manner John A. Whipple, in 1860, took two photographs of the moon, February 5 and April 6, with an exposure of five seconds. The moon changed its position and the two views mounted in a stereoscope showed no longer as a flat disk, but as a solid ball with mountains having three dimensions. By photographing Mars, rotating on its axis, two hours apart, or Jupiter, twenty-six minutes apart, pairs of pictures of these interesting planets are made which vividly show the spherical forms.

Photography without Lens or Camera

Can any one imagine photographing without the aid of camera or glass lens; merely by holding up a sensitized plate to the scene? Yet such was Tiphaigne's magic mirror. A stereoscopic effect on a single plate was also produced through the rare ingenuity of Lippmann. In fact, Lippmann improved on the fly's eye. He embossed both sides of a sheet of celluloid with minute convex surfaces, tiny lens-shaped protuberances on the two sides, which, matching up, form a myriad of transparent micro-lenses. Each little lens has a surface toward the scene slightly more curved than the back. The back is sensitized and is exposed by holding it vertically, facing the scene. Each one of the lenses prints a complete image on its back surface, as may be seen in a microscope. Examined closely by reflected light, nothing appears to the naked eye. Held up and seen by transmitted light, the effect is magical. One sees the scene, natural size, in full stereoscopic relief, exactly as if one looked through an open window at the original scene. Each tiny lens contributes its share to the entire picture, and by moving the eyes the effect is extraordinarily realistic. This is photography without the aid either of lens or camera, and producing a binocular effect without a stereoscope: a sensational achievement.

Photography the Artist of Printing

Printing calls for illustrations. Once these were printed from wood-cuts, hand engraved with great care and effort.

Senefelder found it possible to print from stone, without etching-surface printing. When photography arrived, the way was open to produce scenes and faces with fidelity and engrave them by photo-chemical methods. Books and magazines are to-day filled with fine pictures photo-engraved from camera pictures.

Drawings are photo-etched on zinc in much the way Niepce devised. The coating becomes insoluble where the light falls. The negative, transferred to the zinc surface, reverses the lights and darks on the zinc. Etching with acid removes the portions which must not take the ink. The lines of the original drawings are represented by lines on the plate, which take the ink and transfer it to the paper.

The printing of lines is easy, but scenes and faces present new problems, for they show varying gradations of shades of gray, not merely black and white contrasts. "Grays" are half-tones, and half-tone engraving is an art of vast importance to modern printing. Grays vary from almost black to almost white, because gray is a mixture of white and black. Printer's ink is black, the paper is white. Note how the genius of the printer and photographer blended the black of the ink and white of the paper to produce the varying grays of the picture.

Look at any half-tone illustration in this book, and you see only grays. They appear gray not because gray ink is used, for a magnifying lens shows that the picture is made up of jet-black dots of varying size on the white paper. This is the secret. The ink dots are so small that they blend with the white of the paper as gray. Small dots give light gray, for more of the white paper shows; large dots give dark gray, for more of the black ink appears. But the bare eye sees only tints and shades of gray, no pure black, no pure white, though the lens tells a different tale.

How easily this is done is a surprise to the novice. A negative of a scene is made through a glass screen ruled with intersecting fine lines; say 150 lines per inch each way, 300 inches of ruling per square inch making 22,500 transparent squares, or windows, formed by the intersecting lines in each square inch. The lines stop the light, but through each tiny window passes a point of the picture, the ray falling on a prepared copper-plate. The sky on the negative, of course dark, lets but little

light pass through. For the sky, therefore, the tiny points or dots are small on the copperplate. When the plate is etched with acid the small dots are left standing, becoming peaks on the engraved plate. These peaks, inked by the roller, alone touch the smooth paper which takes off the ink, as you see through the lens. The sky is thus printed light compared with the darker shadows of the scene.

The ruling of fine half-tone screens is an art which we owe largely to the Levy brothers of Philadelphia. It is one of the surprises of photography that cross-ruled lines can break up a picture into dots, and that the negative can vary the size of these dots to give all the tints and shades of gray needed to print a picture on paper. Some fine screens contain as many as 400 lines to the inch, so that in each square inch there are 66 feet of ruled lines, and 160,000 square windows, or more than 5,000,000 clear windows used to produce a single full-page illustration in a book. Each window controls the size of one tiny dot, and does its part in making the picture.

Getting Rid of the Dark-Room

A great sensation was produced among photographers by a recent achievement in photography, ranking in interest with color-sensitizing itself. In 1921, Lüppo-Cramer announced in the *Photographische Rundschau* his discovery that the red dye "phenosafranine" quenches the light-sensitiveness of exposed plates without injury to the undeveloped image. An exposed plate bathed a minute in phenosafranine solution—1 part in 2,000—becomes dead to all light except blue, and retains only one eight-hundredth of its original blue sensitiveness. Lumière and Seyewetz developed such a plate without fogging, near a paper screen lit up from behind with a sixteen-candle lamp. Phenosafranine "desensitizes" the plate, the exact inverse of sensitizing it. How it does so without injury to the latent image is a fascinating mystery, inviting research. The discovery is recent and full of interesting possibilities. By using dyes we may modify, perhaps, the color sensitiveness of the plate so as to make color filters needless. The dark room itself may be entirely abandoned and plates developed in full yellow light under observation. Possibly, even, the developing-room may be lit with a composite white light made of three pure colors, none

of which affect the plate, after desensitizing it to these same three pure colors. In France daylight photography of the stars has been accomplished to stars of the third magnitude, by the use of filters cutting out the blue and with red-sensitized

Photograph by Yerkes Observatory.

GREAT NEBULA IN ANDROMEDA.
An example of the scientific use of photography.

plates. Without waiting for the rare moments of a total eclipse we may yet record starlight bent from its course by the action of the sun according to Einstein's theory.

Photography of Invisible Light

The camera plate records rays to which our eyes are blind. Ether waves may vary widely in length from millions of miles to one ten-billionth of an inch. Of this vast range of waves

the eye can see only those waves not larger than 33,000, nor smaller than 72,000 to the inch. The eye and the camera plate are strictly true radio-receiving sets tuned to receive only certain frequencies or wave-lengths of electromagnetic waves of light. The sensitized plate registers waves varying from 25,000 to 50,000,000 to an inch. For such wide ranges glass is unsuitable, for it is as opaque as iron to very short waves; hence various materials displace glass for the optical parts through which the rays must pass. Photographs are easily made with invisible light. Every different kind of atom can produce a characteristic series of colors or rays differing from every other, just as every musical instrument produces different quality of sound or wave-form. Many such light rays are invisible, and can be studied only by photographing them.

Wonderful Photography of the Sun

The astonishing astronomical uses of photography deserve a volume. The work of Doctor George Ellery Hale of Mount Wilson Observatory will illustrate some of its possibilities. He picks out the light of a given element, say calcium, from sunlight, and with those rays alone he photographs the sun's surface, giving us a map of the calcium cloud distribution on the solar disk. Imagine photographing the distribution of a metal in a circle 800,000 miles in diameter. He can likewise photograph the hydrogen distribution. More bewildering still are his photographs of the sun's atmosphere at different levels, each picture showing the clouds at but one level. This bit of scientific magic seems incredible. It is as though we took a snapshot through two lines of soldiers and photographed the third line only. By dispersing sunlight into its component colors, Doctor Hale picks out just the rays coming from each level in the sun's atmosphere, and from a single element in that atmosphere. Photographs of such rays alone give him a map of a single element at a single level of the solar surface.

Undreamed of power was given to the camera by Röntgen's discovery of X-rays, in 1895, by which we can now photograph through solid wood, metal, or stone. These light-waves are a thousand times smaller than visible light-waves; 50,000,000 end to end would measure just one inch. Such rays from high-

power tubes of recent design, using an electric current of 300,000 volts, photograph through stone walls more than 200 feet away. The camera plates are prepared by mixing finely powdered tungstate of calcium crystals with the silver bromide crystals, and the plates are thus made fifty times faster than before. For example, by using calcium tungstate intensifying screens, a man's hip-bone may be X-rayed in a fraction of a second where once it took forty-five minutes. Altogether the photographing effect has been increased thousands of times in recent years. We can photograph the inner mechanism of a metal clock; or, through several inches of metal, show flaws for which railroad wrecks were once the only test. With the X-ray, the body becomes as transparent as glass; its anatomy an open book. It is a daily practice to photograph the interior of the body to aid the physician and surgeon. Foreign matter, diseased conditions, fractures, and bone settings are readily studied and their treatment planned. Signs of tuberculosis and abscesses are easily noted. The dentist thus studies the teeth, their position in the gums, and even the teeth yet uncut embedded in the jaws. An X-ray of a boy showed not only a gall-stone, its shape and location, but showed the successive layers which made up the gall-stone itself. In fact, the X-ray has already rendered priceless service to the world, and we have hardly begun to realize its remarkable powers.

After our flying trip through the history and possibilities of photography we now see that its uses are boundless, its future limited only by faith, knowledge, and effort. A century ago no dreamer dared predict miracles such as any boy can now work with a camera. In this age of invention no art contributes more than photography. All arts add to its perfection. In turn they are given a new tool with countless uses. From the stone pictures of ancient Egypt, painstakingly cut by chisel and mallet, is a long road to the instantaneous motion-picture of to-day. The uses of photography defy listing; they cover all science, art, and industry; they comprise all professions, occupations, and recreations. Sages once sought by magic phrases —cryptograms—to gain magical power over nature. But the chemical formulas of the dark room are the true cryptograms, translating nature into forms to enlighten and guide mankind.

CHAPTER VII

PICTURES THAT LIVE AND MOVE

THE genii of the Laboratory gave us a mechanical memory of sounds in the phonograph, and a chemical memory of things in the form of the photograph. The motion-picture goes further and gives us an optical memory of movement, a materialized memory of events in actual motion. What we have seen we can recall. Memory, like the film, sensitized and exposed, retains the scene. Projection on the screen is like recollection in the brain. We have given the motion-picture apparatus the power of memory and recall. We may select what it remembers and what it recollects; the film producer does one, the theatre manager the other. What this magical memorizing device means to the world we hardly realize. The "movie" can picture even the impossible, for when we reduce events to a strip of celluloid we can manipulate the events to produce any desired effect on the screen.

Ancient Dreams of the Movies

All inventions have had their prophets. In a wonderful book of philosophy, *On the Nature of Things*, by a wise Roman, Lucretius, written about 65 B. C., occurs this remarkable passage:

> "Do not thou moreover wonder that the images appear to move,
> And appear in one order and time their legs and arms to use;
> For one disappears, and instead of it appears another,
> Arranged in another way, and now appears each gesture to alter,
> For you must understand that this takes place in the quickest time."

This seems to have inspired Plateau who first seriously engaged in research on making pictures appear alive with action. Another prophet was the astronomer-chemist, Sir John Herschel, the discoverer of "hypo," which fixing agent he thought might solve the last problem in the invention of the photographic

process. In 1860, the *Photographic Times* quotes Herschel as saying: "What I have to propose may seem to you like a dream, but it has at least the merit of being possible, and indeed at some time realizable. Realizable—that is to say, by an adequate sacrifice of time, trouble, mechanism, and outlay. It is the representation of scenes in action by photography." He further describes in some detail how these may be made to move on the screen. His remarkable forecast of discovery seems most nearly realized in the motion-picture "news weeklies" of to-day.

The modern type of motion-picture is an American invention based on the well-known principles of some simple household toys. These toys were developed by scientific men in England and Belgium. "Living pictures" were on probation during the period from 1829 to 1890, when, at length, success began to come to the efforts of a host of ingenious inventors. From that time on progress was rapid, and it is chiefly American business enterprise and inventiveness that has developed the motion-picture into the most wonderful art ever evolved by man. It is already the world's incomparable traveller, historian, entertainer, and schoolmaster; it has become more interesting than the printing-press and its art, more eloquent and intelligible than the spoken word.

Why Motion-Pictures Show Continuous Motion

Twenty centuries ago it was known that vision does not stop when an object is removed from sight; the vision persists. Ptolemy's book on optics tells of it, describing a rotating disk with a series of spots which illustrate such persistence. All our lives we blink our eyes, shut off the view, yet do not interrupt sight. The light sensation is not lost by the twinkle of the eye, so we hardly realize that our eyes are shut every few seconds of our waking hours. If we swing a lighted cigar in the dark, the point of light becomes a long bright continuous red streak of light. It appears continuous by the phenomenon of "persistence of vision," which holds the picture long enough for it to appear as a flaming circle.

Motion-pictures were foreshadowed by toys known many years ago. One simple toy, invented by Sir John Herschel,

showed that vision persists. Challenging a friend, he said that one could not see two sides of a card at once; his friend spun a coin, showing head and tail sides to the eye at once. Herschel, however, produced a cardboard disk, an invention of a Doctor Paris, and called the "thaumatrope." On one side of the disk was pictured an empty bird-cage, and on the other side, a bird. Twirling the disk by means of strings attached to the sides, Herschel made the bird appear inside the cage. A very early form of the "thaumatrope" actually showed motion. One side of the disk showed merely an arm holding a bottle, the other a man without his good right arm. On the left side was a string, on the right side a string with a piece of rubber thread attached to it and extending to a second point on the right side of the disk. Twirling the disk in the usual way showed the man holding the bottle above his head; on stretching the rubber, however, the bottle moved toward the man's mouth.

A Blind Scientist Helps on Motion Pictures

Doctor Roget made the first picture toy showing motion, and this was later perfected by Plateau and Faraday. Joseph Antoine Plateau deserves high place in the annals of motion-picture history. He produced the first really successful illusion of motion to the eye by means of a series of pictures illuminated from behind. He studied the persistence of vision and hit upon sixteen pictures per second as the proper number to make the movement appear continuous. When about twenty-eight years old he gazed at the sun for twenty seconds, an unwise sacrifice in the interest of science which cost him his eyesight. Later, temporarily regaining the use of his eyes, he invented his famous "phenakistoscope," a forerunner of the motion-picture projector of to-day. He became professor of physics at Ghent, but at forty-two became totally blind. Many interesting experiments were conducted by his family under his directions, some of his best work being done while he was sightless.

Crude as we would regard it to-day, Plateau's device was one of great ingenuity. A semblance of continuous motion was produced by sixteen pictures on the edge of a disk, shown in quick succession by an intermittent light from behind. He even proposed stereoscopic effects by having two sets of pic-

Courtesy United States National Museum.

THE "ZOETROPE" OR "WHEEL OF LIFE."

In 1833, W. G. Horner devised the "zoetrope," an open drum within which was a series of pictures. As the drum was turned the eye saw, through vertical slits, one picture at a time in such rapid succession that the effect of continuous motion was obtained.

Courtesy United States National Museum.

THE PERIPHANOSCOPE OF 1833.

It was used with a mirror. The succession of pictures was viewed through the small openings in the disk, thus well applying the persistence of vision.

tures made from eight solid models, each in a distinct pose. By viewing with the left eye the series made for that eye, and with the right viewing the other series, the effect of motion in solid relief is possible.

In 1833 W. G. Horner devised the "zoetrope," or "wheel of life"; an open drum, inside of which was a series of pictures; for example, a man in the successive poses of a dance. As the drum turned on its axis the eye saw, through a series of vertical slit openings, one picture at a time in such rapid succession that a girl rope skipping, a boy jumping, horses galloping, or a lumberjack chopping wood appeared in action—a striking effect of persistent vision. The pictures were the beginnings, fragmentary but genuine, of the "movies" of to-day.

Before the motion-pictures we know to-day could be invented, two things were needed. First, a sensitive chemical affected at once on exposure to light; second, a transparent and flexible film to hold the chemicals, record the image, and carry the picture through the projecting lantern. The quick-acting chemical was needed to photograph moving objects which would blur unless the exposure were very short. The chemicals with which early dry plates were coated—the gelatino-bromide emulsion of 1878—were hopelessly slow. Even a quick exposure lasted a second. In a second an express-train travels many feet, so fast that it would appear as a mere blur on the negative. To-day supersensitive chemicals snap a scene in a thirtieth or a thousandth of a second, or, with spark lighting, in less than a millionth of a second.

But a transparent film was also needed for the motion-picture to show on the screen a thousand pictures a minute, and the pictures had to be taken by the camera at the same rate. It was hard to see how glass plates could ever project the sixteen or eighteen pictures a second required for continuous and smooth motion. Doubtless something might have been done with glass after a method proposed by Bettini; but the celluloid film, clear, light, and transparent, invented by Reverend Hannibal Goodwin in 1885, was the perfect material. Its discovery first stimulated Marey of Paris, then others, to the remarkable success which quickly followed. The physical basis of the motion-picture is the film; its soul is light.

In 1861 Coleman Sellers, of Philadelphia, patented the first project for a motion-picture of something like our modern type. His "stereophantascope" was a toy with an endless flexible band bearing a series of step-by-step images of motion. He made a model as a toy for his children, photographed his own two boys, one driving a nail, the other riding his hobby-horse. When the children grew up this forerunner of the machines of to-day was relegated to the attic with the rocking-horse and other toys.

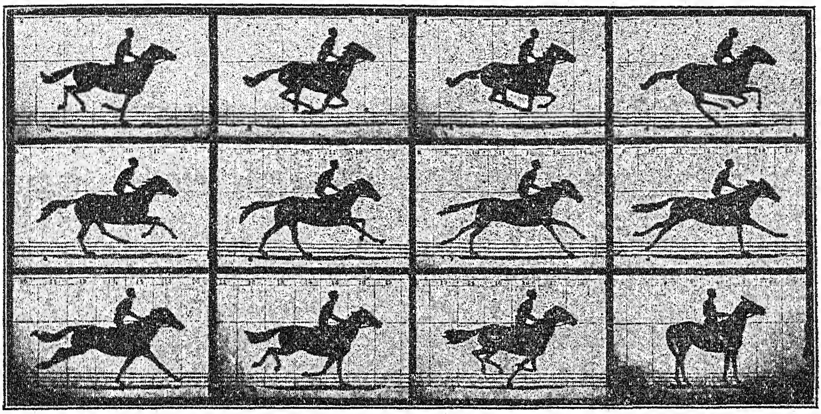
The First Public Motion-Picture Show

The "birthplace of the movies" was Philadelphia. At the Academy of Music, on February 5, 1870, Henry Heyl, of the same city, publicly exhibited on the screen a series of posed pictures showing the movements of a couple executing a waltz. While certainly the first life-sized exhibition of animated screen pictures, it was not produced by the photography of moving persons. The wet-plate process of that day required time exposure, and the dancers, one of whom was Mr. Heyl himself, assumed the six successive pose phases of a waltz movement. The pictures, repeated three times, were placed around the edge of a disk, while Mr. Heyl used a step-by-step motion in strict time with the waltz music of the orchestra.

At the Sacramento race-track, about 1872, some lovers of fine horses, among them Leland Stanford, were discussing the motions of running horses. The point at issue was whether a horse ever has all four feet off the ground at once. Stanford contended it had; others disputed it, saying that the horse would have nothing to support it if all four feet were off the ground. A wager was made, which they sensibly decided to settle by photography. Stationed at San Francisco was Eadward Muybridge, of the staff of the United States Coast and Geodetic Survey and in charge of their photographic surveys. The horsemen made up a purse and engaged Muybridge to settle the point by the camera. Wet plates were not easy to handle, and instantaneous photography was out of the question. Muybridge placed a long white sloping screen along one side of the track, and a battery of twenty-four cameras along the other side. As the horses ran by they broke threads stretched across the track, and these successively operated the camera shutters. In all a

half million plates were used, some of the exposures being as short as one five-thousandth of a second, too short for the details of the picture, but showing the horse more as a profile or silhouette. The resulting photographs proved conclusively to the interested horsemen that a galloping horse does, at times, have all four feet off the ground.

Muybridge was an important link in motion-picture history,



Courtesy Stanford University, Palo Alto, California.

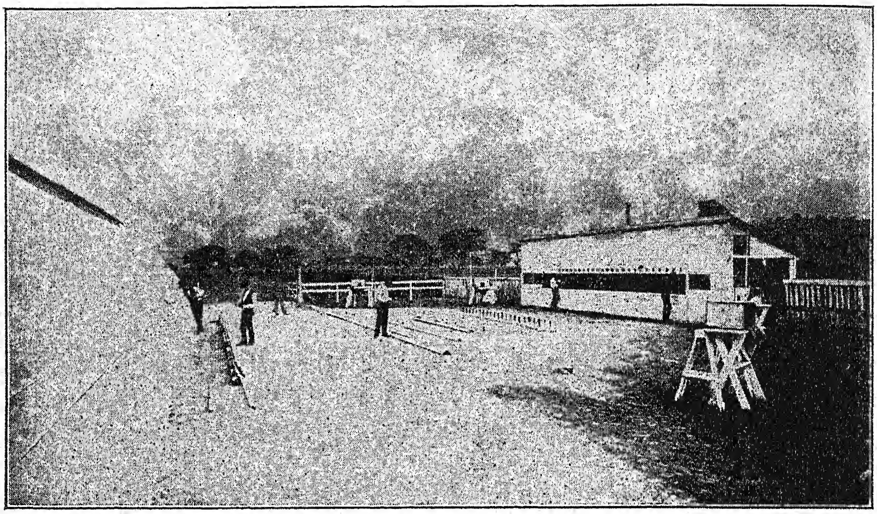
MUYBRIDGE'S PHOTOGRAPHIC STUDY OF A RUNNING HORSE.

From time immemorial artists and scientists had disputed the question whether or not a horse's legs in running all left the ground together at any stage. To obtain a scientific answer Senator Leland Stanford financed a series of elaborate experiments conducted by Eadward Muybridge. Photographs were made with a battery of cameras, with shutters successively operated as the horses dashed by. Thus for the first time the movements of a running horse were analyzed. That all four feet leave the ground the pictures here reproduced prove.

even though he began with the aim of producing separate photographs for individual study. He gave keen attention to the evident possibilities of his experiment. His book, *The Horse in Motion*, excited nation-wide interest. Its publisher, J. B. Lippincott, of Philadelphia, was a lover of fine horses, and gave funds for continuing further work in that city. The outcome was *Animal Locomotion*, a monumental work in eleven volumes, containing 100,000 pictures of horses, athletes, birds in flight, and other living subjects. The pictures showed the work and play of men, women, and children of all ages; how pitchers throw the baseball, how batters hit it, and how athletes move their bodies in record-breaking contests.

Making Animal Pictures Move on the Screen

Muybridge tried to induce Edison to combine the phonograph with a device of his own called the "zoopraxiscope." With this invention Muybridge had already projected pictures at rates between twelve and thirty-two pictures a second to



From "The Horse in Motion," by Eadward Muybridge.

HOW MUYBRIDGE MADE HIS PICTURES.

In order to analyze the movements of running animals and men Muybridge devised a battery of cameras, the shutters of which were electrically opened and closed. Thus photographs were made of a running animal at intervals of twenty-seven inches; the exposures were about two thousandths of a second each, and sometimes one five-thousandth of a second.

illustrate his lecture on animal movements. Edison, busy as a bee, was unable to spare the time, so Muybridge perfected his own device, and exhibited it at the Paris Electrical Exposition in 1881, many years before the kinetoscope. That year Muybridge met Doctor E. J. Marey, a Frenchman keenly interested in graphics. It was a meeting of two enthusiasts. Together they founded the science and art of "motion analysis," which in the hands of Frank B. Gilbreth was destined to become an accepted method of great power in the study of motion economy. Edison later met Marey, and, inspired by the Frenchman's enthusiasm, he perfected the kinetoscope.

Who was this Doctor Marey, and what was his part in motion-picture evolution? He was a member of the French Academy, devoted to the subject of the graphic method, and author of the greatest work on that subject, under the title of *La Méthode Graphique*. Stirred by Pierre Jules Janssen's photographic gun, which took intermittent pictures of the transit of Venus across the sun's disk in 1874, Marey, eight years later, constructed his own "photographic gun" by which, with a single lens, he could take twelve pictures in quick succession on plates evenly spaced on the rim of a disk. In this way he recorded the phases of the flapping of a bird's wings. Marey was perhaps the first to use a single lens and, in 1887, probably the first to use celluloid film after its invention by Goodwin. His work is classic; his influence on American invention profound.

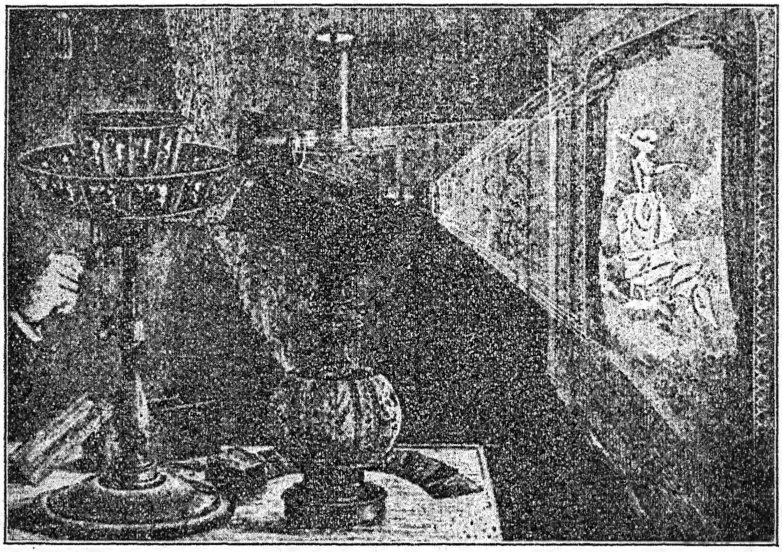
About 1889 another Frenchman named Raynaud exhibited on the boulevards of Paris his "praxiscope," under the name of "Théâtre Optique," using a series of lantern scenes painted on a band of gelatine. A light beam passed through the gelatine pictures, reflecting them to the eye by means of mirrors. The device was in successful use in Paris and fairly popular until the present motion-picture machine displaced it.

Experiments Forecast the Coming of Motion-Pictures

Mr. Friese-Greene, early in 1890, was experimenting on taking photographs in rapid sequence, and speaks of "exposing a negative on a travelling band 3,000 times in five minutes." He says: "My blood was fired with enthusiasm, for I thought of taking a scene in Hyde Park, or in the City, where the ceaseless stream of life is never ending, by the machine camera, one day, and producing in the course of a few hours a paper which can be delivered to the public showing, true to nature, all the movements of life, or anything that might be of interest which was photographed at the time." It is understood that he was not necessarily speaking of motion-pictures in our sense, but rather "series pictures" to be separately inspected at leisure. His interest reminds one strongly of Herschel's forecast of 1860, "the vivid and life-like reproduction, and handing down to the latest posterity of any transaction in real life, a battle scene, a debate, a public solemnity, a pugilistic conflict, a harvest home,

a launch, indeed anything, in short, where any matter of interest is enacted within a reasonably brief time, which may be seen from a single point of view."

Thomas A. Edison could always be counted upon to play his part in the mechanical evolution of new inventive arts. When the time seemed ripe for success he gathered the threads



From Eder's "Ausführliches Handbuch der Photographie."

THE PRAXISCOPE.

About 1889 Raynaud exhibited in Paris his "praxiscope." He used a series of lantern-slides painted on gelatine. Light passed through the gelatine pictures, and this was reflected to the eye by means of mirrors. The disk was very popular until the present motion-picture was invented.

of the needed elements. His chief contribution to the motion-picture was perfect photography and precise mechanism. Stampfer, in 1833, and Devignes, in 1860, proposed the use of film; Marey used it in 1888, and the same year Le Prince proposed the perforation of the film, with a sprocket for the film movement for which he had filed a patent application in 1886. In 1876 Donisthorpe had exhibited his "kinesigraph," in which a strip of views was exhibited by intermittent beams of electric light. In 1889 Anschütz, of Prussia, exhibited his electrical tachyscope; at first a disk rimmed with pictures, later a strip

of pictures illuminated from behind by an electric spark as each picture passed the eye.

The Edison laboratories appear to have begun work on the kinetoscope as early as 1888, under the direction of W. K. Dickson. The device was patented in 1893. It was really a peep-show in which a single observer could view scenes in motion for more than a minute. The photography was excellent; the mechanism worked smoothly. The film moved continuously and carried a series of very small photographs, each one lit up by an electric spark for one seven-thousandth part of a second, in some machines about one-half of this time, both speeds being such that the image was sharp and clear. The machine was probably the last, as Plateau's was the first, to use intermittent illumination with steady movement of the film. To-day all film moves by jumps both in camera and projector —unless we except the newly perfected ring-prism and disk-prism devices of C. Francis Jenkins.

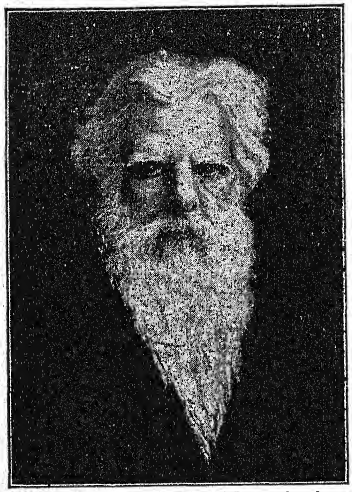
Edison's experiments were prolonged by his attempt to produce a cylinder picture record after the manner of his then successful phonograph cylinders. Cylinder picture records were made as early as 1888, showing the antics of John F. Ott, a mechanic in the Edison shops. The kinetoscope was not adapted to screen-showing in the theatre, and the type later adopted was that of the Jenkins projector which is now used the world over, and which makes use of powerful light sources and an ingenious intermittent mechanism for the film movement.

Jenkins Invents the Motion-Picture Machine of To-day

So matters stood in the early nineties, with inventors like Reynaud, Muybridge, Marey, Edison, Jenkins, and others at work. The nature and principle of improvements which had to be adopted to make the full-size theatre projector a success and the camera a practicable portable instrument were generally known. Mr. Jenkins says that no one inventor ever invented anything, that many hands and heads at work gradually evolve the successful machine. Notwithstanding this, the priority of producing "the first successful form of projecting machine for the production of life-size motion-pictures from a narrow strip of film containing successive phases of motion,"

was awarded to C. Francis Jenkins, of Washington, D. C., by the Franklin Institute of Philadelphia, after a searching inquiry into the true priority of invention of the motion-picture machine. For this invention the Institute awarded him the Elliott Cresson gold medal.

C. Francis Jenkins was once a stenographer in the Treasury Department, attached to the Coast Guard. Active and inge-



By courtesy of University of Pennsylvania.

(Left) PORTRAIT OF EADWARD MUYBRIDGE PAINTED BY ELSA KOENIG NIETSCHE.

(Right) C. FRANCIS JENKINS.

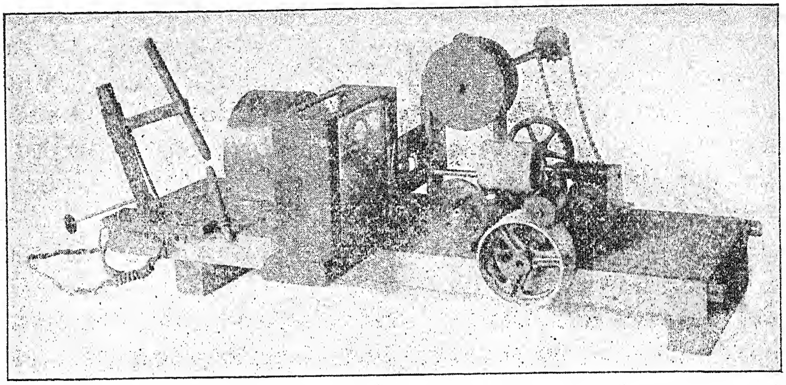
Jenkins invented the first practical projector for throwing on the screen life-sized pictures from films taken of living moving objects.

nious, he was interested in representing motion on the screen about 1891. After work each day, he experimented in his shop. Taking ordinary spool film, sold as a supply for kodaks, he cut it into narrow widths and spliced it with a film cement of his own devising. His unwearied efforts overcoming one obstacle after another finally resulted in his now-famous "phantascope," which he showed privately to his friends about 1891 and later. In June, 1894, the success of the "phantascope" was such as to justify a public demonstration. Back to his home town he carried the new machine; Richmond, Indiana, saw the first motion-picture feature—a "first national produc-

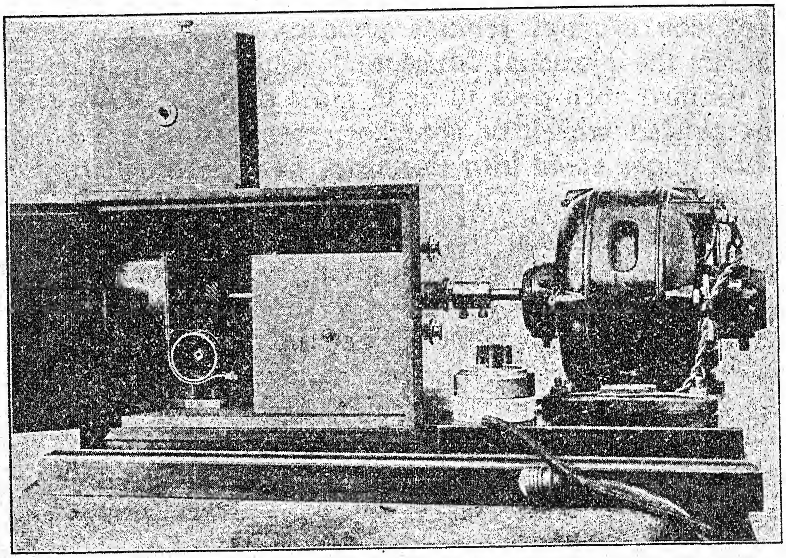
tion." It was a stretch of film picturing a dancer, then appearing at a local vaudeville house in Washington, and the film was taken on the present site of the New Willard Hotel. Much to Jenkins's disappointment, his mother, good Puritan that she was, objected to the subject; the father, however, displayed due appreciation, both of the subject and the invention. The town newspaper, the *Richmond Telegraph*, in its issue of June 6, 1894, told in head-lines the news of the first public motion-picture given by the new machine.

The positive film in the Jenkins or any other modern machine is really a series of magic-lantern slides. It is the star performer; for the screen is fixed, lights and projector stationary, audience seated. The film alone moves. Its wonderful motion gives a timed sequence to the screen pictures, and this sequence is the soul of the motion-picture art. Let us study a moment the original Jenkins phantascope of 1894, later deposited in the National Museum. An electric motor turns a wheel rimmed with pegs to fit in holes on the edge of the film. As the pegged wheel, or sprocket, turns, it unwinds the film from the upper spool into the beam of light which throws the picture on the screen. The film, passing before the lens by jerks, stops only long enough to let each picture appear an instant on the screen, then passes quickly, giving way to the next picture, or frame.

How simple all this seems! Yet the film is at once a troupe of players and their automatic manager. Each film picture dashes into the spot-light, stops an instant to give the audience a view of its image, then gives way to the next. It is a mechanical feat to jump sixteen or eighteen times a second during an entire evening's performance. The entrance and exit of each picture are concealed by a curtain called a "shutter," a metal disk which shuts off the light during change of pictures, as does the curtain for the real stage. Of course all this is the principle of the magic lantern during its heyday: picking up a slide, placing it in the lantern runway, flashing it on the screen, removing it, and placing it on the used pile. But to change the "slide" sixteen times a second—to present to the spectators, 50,000 separate pictures at the rate of a thousand a minute, is surely a triumph of machine design and operation.



FIRST JENKINS MOTION-PICTURE PROJECTOR OF THE TYPE NOW IN GENERAL USE.

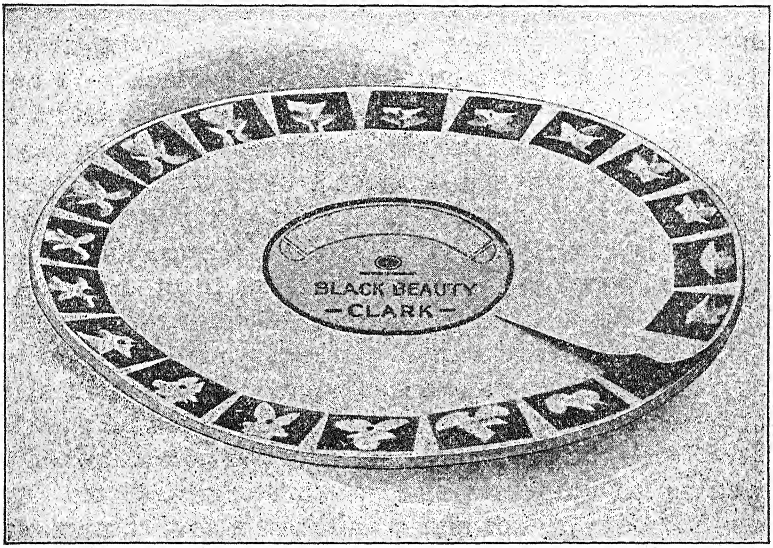


HIGH-SPEED JENKINS CAMERA.

Pictures have been taken with this instrument at the rate of 100,000 a minute.

All this was evolved through the phantascope of 1894. Jenkins took his machine to the Cotton States Exposition at Atlanta, where only a few hundred were interested enough to see it in operation—a common fate of new things. The following year, in France, the Lumières projected pictures on the screen

with their cinematograph, using a perforated film. Jenkins, by his invention of the phantascope and his pioneer work, has earned a secure place in motion-picture history. He has perfected the sending of still pictures by radio. His later work deals with the broadcasting of motion-pictures by radio; a remarkable possibility. The author has recently seen the shadowy outlines of his own fingers moving across the screen, crudely transmitted by radio—the beginnings of a new art.



MOTION-PICTURES ON PAPER DISKS.

Motion-pictures for the home on a number of paper disks, each having a radial slit to permit the projecting mirror access to each series in turn on the principle of the spiral staircase.

The Beginning of the Motion-Picture Industry

When motion-picture cameras were first used, those who had "rights" took a lively interest in the subjects to be filmed. In the nineties, William H. Selig and others went from town to town taking, here a local fire company in full action, there a passing train or some simple street scene, later exhibiting the pictures in local halls. The "Empire State Express"—a thriller of those days—thundering across the screen to the rattle of the snare-drum, always brought applause. But film sub-

jects were fewer than those of the magic-lantern slides, and the young art actually seemed destined to an early collapse; interest died down and its dramatic future was unforeseen. During the Cuban War, however, moving-pictures of battleships ploughing through the sea and troop-ships carrying returning soldiers revived the waning popularity.

About 1894, Alexander Black had the genius to conceive and execute a magic-lantern play. To-day we would find it tame. But during its hour, "Miss Jerry" was hailed with delight, and the novelty of it attracted wide attention. In no sense a motion-picture play, it was a link between "living pictures" and the modern motion-picture play. Mr. Black says he was trying to tell stories by photographs. A group of camera studies tossed together and named "Ourselves as Others See Us" was his starting-point. To produce a picture play was another matter; the pictures had to develop the plot progressively and tell the story in a long series of separate photographs.

In "Miss Jerry" there was no attempt to produce the illusion of motion, but rather to blend one picture with the next. Mr. Black projected about three pictures a minute by a stereopticon with a dissolving-view attachment. Camera and scenery were adjusted so that each new picture registered on the screen accurately with the preceding one; only the actors moved from one position to another. The whole story was told in 250 pictures in about an hour and a half, and a text thrown on the screen filled in the gaps in the story. The settings were not natural, but made on a regular stage. Artificial as it would doubtless seem to us, this was an advance toward the modern camera play with its marvels of realism.

Early film plays were chiefly comedies full of slap-stick and camera trick work, well known in principle before the motion-picture arrived. In the late nineties, however, Méliès, a French producer, devised many new motion-picture tricks which have scarcely been excelled. In 1900, Zecca, a Pathé director, produced in France one of the first true photoplays, "L'Histoire d'un Crime." With it the photo-drama arrived, and following Henri Lavedan's scenario of "L'Assassinat du Duc de Guise," the photoplay became a fine art, speedily arousing the highest enthusiasm.

Producing a Photoplay

To the motion-picture "all the world's a stage." All nature is its scenery; all men and women its players. The scenario writer may call for an ocean, a forest, a river, a volcano, or an Oriental city. The location man or scenic artist must produce just what is called for: Alaska snows, Sahara sands, a New York tenement, or a thousand scenes from as many lands. The historical expert must know all the proper names in the language and not fail in giving accuracy to the details of an event.

Building up a motion-picture play is not unlike, in principle, the construction of a house. It is finished bit by bit; a hundred parts are separately developed in a hundred places, without seeming order or sense, until final assembling. Between "shots" the big studio is a bedlam of building, rehearsals, coaching, dressing, and business—all working toward the finished, well-rounded "big-feature" play. The director paints his great scenes with living characters; under his direction the players become as mannikins, rehearsing for the final action, every actor tense with the team-work a photoplay demands. When ready, the director shouts "Camera! Action!" Now every move must be perfect; for the cameras are registering the scene for the world and posterity. Little wonder the motion-picture studio attracts thousands; here the young actor and actress will find opportunity, inspiration, and instruction waiting on them; and yet, even after success is attained, they must be prepared to work very hard.

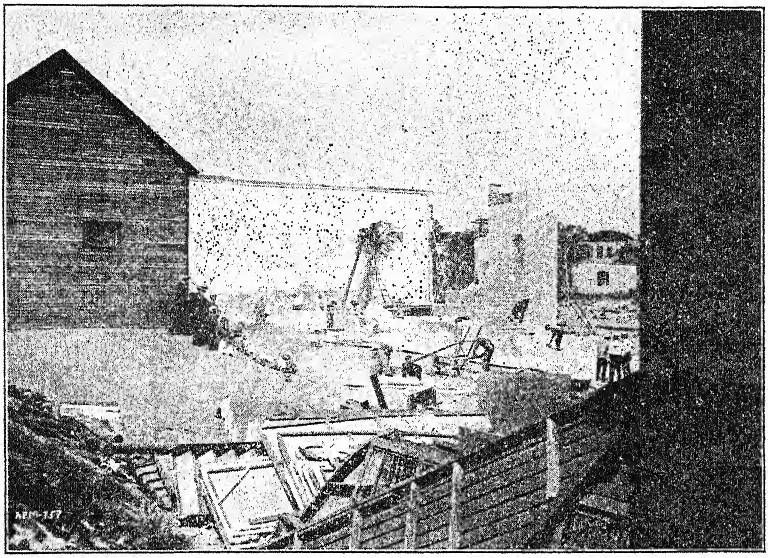
A veritable army of workers is needed to produce the sets for a modern scenario; practically all kinds of building craftsmen and artists. The resources of centuries of theatre lore are at hand, with countless new devices added. From the scenario the director plans all "sets," or scenes, and their construction in the studio calls for considerable skill. The film of "Broken Blossoms" had to be perfect in local color to satisfy the artistic sense of the director. Newly made rooms in the studio must be "aged" by adding signs of wear and old stains. The property-man from his museum of accessories—his old curiosity-shop—must produce anything from a pair of snowshoes to a

jewelled crown. His ingenuity is tested and dependable; the word "can't" is not in his lexicon. Either he has everything or he will make it or get it. From private homes, museums, junk-dealers, pawn-shops, curio bazaars, and a thousand sources, he harvests in his properties, without which his realism would fail.

The life of the player of the studio is adventurous compared with that of the theatre actor. In the 500 scenes which a modern "superfeature" may call for, some are sure to involve hazardous exploit. Outdoor scenes must be played so as to seem real, and not like acting. Hubert M. Kittles, substituting for the high-salaried "star," was in bed for weeks with broken bones after a realistic motorcycle race, in which the story called for a real tumble. Having been a racer he said: "I won't do a thing half-way," and he refused to slow down as he passed the camera. His fall was as genuine as were his resulting injuries, while the hero whose place he took went unharmed. The principals in "Way Down East" are reported to have had pneumonia following exposure during the now-famous snow-storm and ice scene. Mary Pickford insisted on acting through the pelting rain in "Lovelight," the director shouting instructions from the shelter of his umbrella. Fairbanks, diving through the court-room window in "The Nut," was seriously injured. In the "Pride of the Clan" the rescue scene from the sinking boat almost ended in disaster, because of the effort of the star to save her pet kitten.

On the screen, danger is not always make-believe. William S. Hart was hit by a china vase, thrown in place of one of papier-mâché, called for by the director. Wild animals give thrills not in the scenario. Public opinion, however, does not tolerate deliberate sacrifice of life, as in an actual scene showing a horse and buggy falling off the cliff road. But sometimes startling effects come by chance. A picture play once showed a runaway fire-engine team dashing into the camera, fortunately without damaging the film, and the public had an unusual thrill. Films of real danger and reckless exploit are frankly advertised as such. Probably in none was the risk so evident as when Williamson fought and killed in deep water the barracuta, a shark-like fish, his only weapon being a knife.

On the other hand, the danger is often more real than apparent. A camera man at a great risk once secured a modern battle scene in Mexico; though genuine enough, it was rejected as too tame for the public. A battle picture has become a standard symbol which even realism dare not violate. But the camera men, whom we know only by their wonderful screen



Courtesy Paramount Pictures.

PROPERTY DEPARTMENT LAYING OUT A DESERT AT THE LASKY STUDIO.

pictures, run serious risks. Like soldiers they are under orders, and must be ready to take any scene from its best point of view; from the cables of the Brooklyn Bridge to following an automobile race at a hundred miles an hour.

Miraculous Effects Not Always What They Seem

The play requires the action of the players, but incidental effects must often be manufactured. If a cyclone is needed, an airplane propeller may be used, and the effect on flimsy structure is startling. If a blinding sand-storm be part of the story, handfuls of sand or confetti showered before the camera lens produce a realistic storm. If the scene be laid in the interior of a steamer's cabin, the effect of rolling and tossing must be

produced; in this case, since the stage is nailed down, the camera man must rock his camera while exposing his picture so that the film gives the realism. Whether the camera man can or can not get near enough, and though it be too dark for purposes of photography, the final downward plunge of the doomed vessel must positively be shown on the screen. He therefore "shoots" the ship as long as he is able. The scene is later completed in a small tub with a tiny model. On the screen, of course, the exciting incident appears convincingly real.

In a recent screen romance a stork flew over a house and dropped a little white bundle down the chimney. In the studio, the scene was only a two-foot house with a tiny cardboard stork moved across the scene by wire. A wild-west story shows a "close-up" of the town music-hall. On the screen it appeared full size; in the studio it was eighteen inches wide. There is no limit to the ingenuity used in preparing films. The "Thief of Bagdad" shows the magic carpet of the Arabian Nights in full visual realization, and the cloak of darkness working its mystifying effects.

The genius of the motion-picture camera can perform miracles. It can put back the clock, recall the setting sun, and retrace chronological incident step by step in bewildering accuracy. When we reduce events and actions to a strip of patterned celluloid, we become wizards, and with a pair of scissors and a little film cement we can reverse history. We can cut out sections so that cause and effect are no longer connected, and magical appearances or disappearances result. A condemned man ponders alone in his cell. Suddenly two spectres appear seated beside him, charging him with his crime. To produce this effective illusion, the film technic is simple. The camera stops turning, the two spectres enter the scene, sit down by the condemned man, and the camera starts again. The entrance is omitted, only the sudden apparition is apparent. We can transpose events at will, or invert them so that events move backward in time. In a pillow fight, the awakening of the children and the bursting pillows when projected with reversed film invert the story, so that the feathers rush back into the pillow-cases, the pillow-cases go to their places, the children lay down their heads and return to sleep. The camera

can be turned upside down to show men walking like flies on a ceiling, or turned through ninety degrees to show an actor walking up a wall. With suitable devices men appear flying through space, the background disappearing. A set may show the side of a house lying flat on the ground; by crawling along the ground the actors appear on the screen as if climbing vertical walls in most dangerous exploits.

The camera may also be slowed down, so that when the resultant film is projected at full speed on the screen, the time between pictures is so brief that the players move with impossible rapidity. On the contrary, by turning the camera crank faster the pictures projected at normal speed show the "slow motions" which so amuse or surprise us. Double exposures introduce weird effects. Actors converse with themselves in dual rôles, both characters being shown on the screen at the same time. Mary Pickford "doubled" Little Lord Fauntleroy and his mother, "Dearest." Buster Keaton, in trick comedies, uses many clever devices; one comedy showed him taking the part, simultaneously, of the entire orchestra, the minstrel troupe, and the audience. The film section, taken for each, is separately exposed, the portion of the scene to be reserved for the next exposure being cut off by a mask before the camera-plate.

Natural Colors in Motion-Pictures

The regular stage play still has the advantage of color in costumes and scenery. Successful colored motion-pictures have been shown, and may find their way slowly into general use. At first, like magic-lantern slides, films were colored by tedious hand-work. As in printing and photography, so in the kindergarten days of motion-pictures came the striving for natural colors. The task of coloring lantern slides is not easy, but coloring a motion-picture film presents considerable difficulty. A thousand pictures must be colored for each minute of the screen picture showing, or 120,000 for an evening's entertainment. The cost is enormous. The projection of a lantern slide may stay on the screen for half a minute, but a single unit of the motion-picture series lives before an audience but the twentieth part of a second.

A better natural color effect came with color photography, which would have been more successful but for the slow action of red on the sensitive film. A thirtieth of a second exposure by the camera is as much as can be allowed. In this time blue colors register easily, green not quite so well; but red, at least on ordinary film, registers scarcely at all. A black-and-white film picture of an orange grove shows the fruit black.

Dicyanin is now used to sensitize the film, so that the slowness of the red is conquered, and the road to real color motion-pictures is wide open. So sensitive is dicyanin that photographs may be taken from the clouds in one two-hundredth of a second from a height of over a mile.

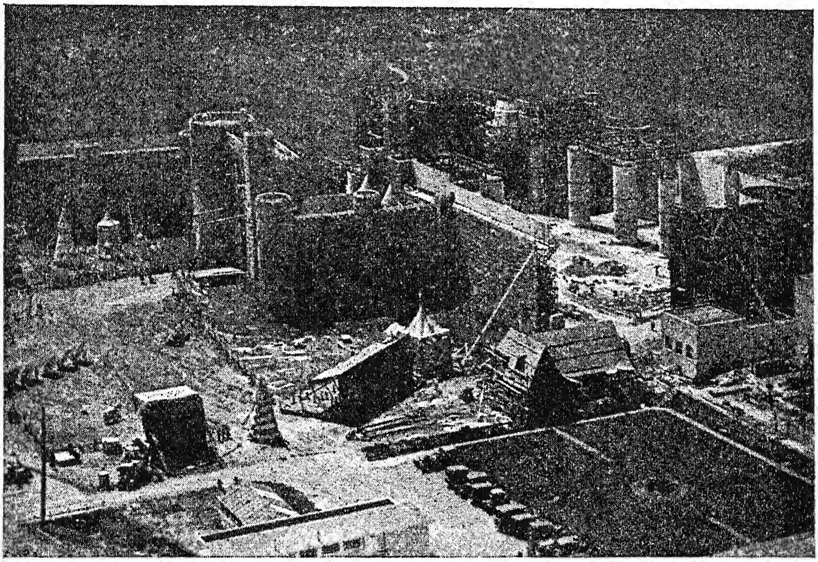
Attempts, somewhat successful for quiet scenes, have been made to produce color effects photographically. In London and Berlin, about 1912, George A. Smith showed pictures in color taken by the kinemacolor process. Alternately through red and green gelatine, ordinary, uncolored film pictures were taken to record in varying shades of gray the green and red elements respectively. These pictures were projected on the screen alternately through the color screens. The red and green pictures thus appeared in turn on the screen so fast that they blended in the eye to produce the natural colors. Unfortunately, since an object moving across the scene was not in the same position in the red and the succeeding green picture, the object appeared fringed with red on one side and green on the other; a serious defect in any color process intended for motion-pictures.

To obviate the failure of the red picture to register with the green picture following, Arturo Hernandez ingeniously placed the red on the face of the film and the green on the back, exposing them to the scene simultaneously by a clever system of reflectors. Promising as this and other two-color methods were, the three-color system gave more perfect results.

In 1861, Maxwell showed that red, green, and blue pictures of a scene could be made to reproduce all the natural colors on a white screen. A. Sauve patented a cinematograph process based on Lippman color photography. In 1913, however, Gaumont came out with a three-color scheme by which, either across or along the film, three simultaneous exposures were

made, of the red, green, and blue elements of the picture. The film itself was not colored, but the projector sent the light beam through appropriately colored screens; the three pictures, superposed simultaneously on the screen, gave a beautifully natural color effect.

Public appreciation of true color realism is great enough to justify rapid extension to all motion-picture work. "The Great



Courtesy United Artists.

THE NORMAN CASTLE WHICH WAS ERECTED FOR DOUGLAS FAIRBANKS'S PRODUCTION "ROBIN HOOD."

An example of the lengths to which modern producers go in building elaborate and expensive sets.

Adventure," a 1922 "superfeature" filmed in England, screens in full natural colors. The definite approval of colored pictures by the public will effect not a few changes in the studio. There, at present, the powerful lights are too brilliant for white garments to be worn; even for wedding-dresses, yellow and other neutral colors alone are used. When color photography comes into general favor, all sets, including scenery, properties, accessories, and costumes, will have to be made in natural colors; everything must be true to life, and harmonious in combination and contrast. This will entail a further expenditure of millions

of dollars, and call for a new form of artistic skill. In the color play, "Wonders of the Wasteland," artistic attention was given to the costume and scenic colors, with great success.

Making Motion-Pictures Talk

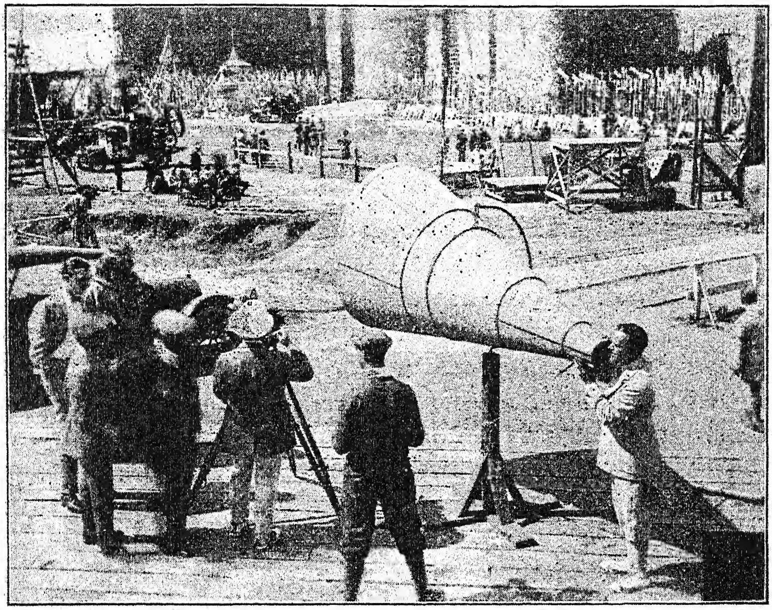
To add sounds to the motion-picture was an early dream of inventors. The many difficulties in connection with it even prevented Edison from perfecting the kinetophone, novel and ingenious though it was. Sounds must be loud enough and rendered with proper modulation to satisfy the audience. They must be exactly timed with the moving lips, the shot of the gun, or whatever sound source is pictured. To give all the natural sounds, speech, and music which accompanies the drama on the regular stage, would be very costly. Perhaps cost is the greatest obstacle at present until public demand insists on greater realism, or until a far-seeing producer brings us the new art.

Edison's kinetophone was a bank of several phonographs conforming with the pictures by electrical means. They were assembled behind the screen, and presided over by an attendant. It was not a success. The discriminating ear was too accustomed to the superb enunciation and tone quality of the legitimate actor to enjoy the thin voice of a mechanical substitute. And yet, the kinetophone was the beginning of a new art that will surely attain the perfection of the motion-pictures themselves.

A very ingenious system of sound rendering was developed abroad in which a steadily moving film records the speech-waves as lights and shades, the varying brightness corresponding to the variations in the sound-waves. In the projector a light beam passing through the film is varied in brightness in the same manner, and it actuates a selenium circuit so that it carries more or less current following exactly the original sound-wave form.

The trend of machines to-day is toward automaticity, and the sound rendering must be as automatic as the pictures themselves. Probably for several reasons the sounds will not be produced actually on the stage. Light outspeeds sound, and the synchronism of sound and action on the stage would be destroyed in the rear of the theatre. Again, the softer letters of

speech are completely lost even a few feet from the stage. The appeal to the ear must be flawless. Beginnings have been made, and the science of acoustics is now so well able to analyze all sounds and record their curves that the future movie hero of



Photograph by United Artists.

DIRECTING A MOTION-PICTURE PLAY.

The director's stand in one of the scenes taken of "Robin Hood." One thousand two hundred "extras" took part in this scene. Douglas Fairbanks at the megaphone.

the screen may have a vocality comparable to that of his more substantial brother, the actor.

Diagrams That Move as if Alive

An astonishing kind of motion-picture work is the animated diagram, or cartoon. A thousand or more sketches are drawn by hand, each sketch differing a little from the preceding one, and the movie camera snapshots each drawing once or twice. When thrown on the screen in quick succession the diagrams appear to move as if alive. The animated diagram is the old zoetrope, or wheel of life, raised to a new art by the camera to give it scope and speed. To prove that it could be done

Windsor McKay made some 10,000 hand-drawn sketches, showing the playful antics of "Gertie, the Dinosaur," among her prehistoric cousins, rooting up and devouring trees, tossing rocks, and drinking up a small lake. It took McKay a week to draw the sketches needed to show one opening of "Gertie's" mouth.

Hand-drawn diagrams of surgical operations show each cut of the knife, and its effect on the inner tissues and organs is seen more intelligibly on the screen than by a direct view. A complex process is made perfectly clear and memorable by this method. The wonder of the animated diagram is that expert knowledge is made more vivid in a fraction of the time required by words alone. The film diagram of the Quebec bridge disaster was more graphic than a photograph, and the three-minute film-story showed the cause and method of collapse, not as the casual observer saw it, but as the technical expert disentangled the inside story after weeks of study. How the Hudson River tubes were set in place, the movie diagram explained in a few minutes. West Point students, formerly taught the making and use of bombs by a course of lectures, were found to gain a clearer knowledge of the subject from a fifteen-minute animated film summary than from the whole course of lectures.

A perfect system was needed to convoy our soldiers to France during the Great War. This was rehearsed and perfected by animated diagram. Each ship became a graphic element on a table-map. As the ships were moved through a manœuvre, the movie camera snapshot each formation in a series which showed the entire movement. Trained officers then viewed the fleet in action on the screen as each ship did its bit in every emergency—a dress rehearsal to make perfect a naval enterprise unequalled in history. Imagine the strategy of football put into a film diagram with scarcely a word of explanation. Can we imagine the effect on the inside perfection of the plays?

To-day, an inventor may show his device by a sketch which comes to life on the screen, performing as if actually built and in full natural operation in a manner that photography alone could not show. A thousand uses are being developed for this new art which, for the purposes of designers, inventors, lecturers, students, and teachers, is without rival for explanation, clearness, and interest

CHAPTER VIII

FROZEN MUSIC AND SPEECH—HOW EDISON INVENTED THE PHONOGRAPH

PAGANINI is still revered as the greatest of violinists. A hundred years ago he moved audiences to tears. The world rang with his praises. How does he compare with the great violinists of our day? Was he so astounding to those who heard him because he was indeed a greater artist than any who have since played a Guarnerius or a Stradivarius, or simply because he was the first to acquire a skill which we would consider adequate? We can never know. His music is stilled. And what of the matchless voice of Malibran, of Chopin's delicate rendering of his own nocturnes, of Garrick's moving interpretations of Shakespeare? We must rely upon the cold printed words of contemporary enthusiasts and critics. How was English spoken in Shakespeare's day? Would we understand the actors who played in the Globe Theatre in Queen Elizabeth's time? Perhaps—perhaps not. We have no standards of comparison. We can only guess from rhymed poetry, from the accents of blank verse how Shakespeare pronounced the English tongue. What would we not give if we could revive the voice of Patrick Henry and thrill, as his hearers once did, to his "Give me liberty, or give me death!"

When we deal with sound we deal with a fleeting thing. It dies a moment after it is born. For what is sound? Nothing but a disturbance of the air. We speak, and from our mouths and lips come puffs, but puffs so wonderfully formed, so infinitely varied in frequency and strength that nothing short of a miracle happens. We receive these puffs on our ear-drums; we translate them; we give them the meaning that they are intended to convey; in a word, we hear. Because he expressed himself in mere disturbances of the air, in pressure-waves or puffs, the great orator or singer or musician of the past lived only for his own time. When he died he became but a tradition.

Dozens of inventors had attempted to immortalize the artist of sound long before Edison succeeded literally in embalming human speech and musical notes and revivifying them at will. There was Leon Scott, for example, who invented the "phonautograph" in 1857, sometimes erroneously referred to as the forerunner of the phonograph. But what was it? Nothing but an instrument by which the puffs of air that we call sound were made to vibrate a marker, which in turn played on a piece of smoked paper and thus traced wavy lines in soot. Scott had invented merely a way of enabling sound to trace a symbol of itself—a method of sound-writing. His wavy lines scratched in soot were no better than printed words when it comes to informing us how the great singers of his day trilled their notes; for it was impossible to make the wavy lines talk or sing again.

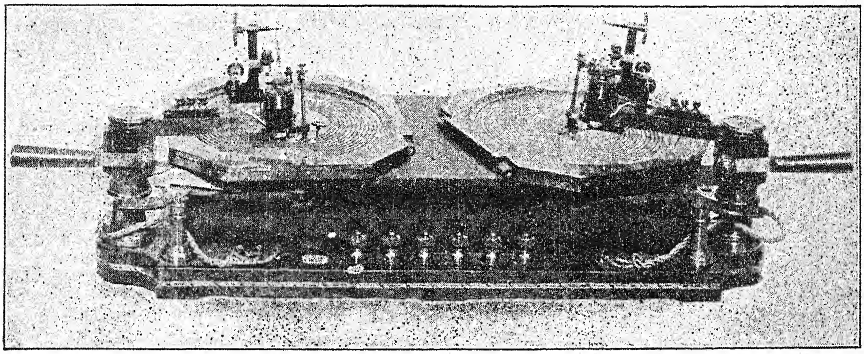
It was not until Thomas A. Edison invented the phonograph, in 1877, that the world was enriched with an apparatus which did for speech exactly what the photographic camera did for light. How original was the invention is shown by the course in the United States Patent Office of the specification in which it was first described. A patent is not granted in this country unless the invention that it discloses is new—new in the sense that it is markedly different from any related device that may have been known or used before. Edison filed his application for a United States Patent on December 24, 1877. A patent was issued to him on February 19, 1878. Not a single "reference," as it is called, was cited against him, which means that the examiners of the Patent Office had been unable to find a description of anything even remotely like his phonograph in all the technical literature that they were required to ransack in accordance with the regulations.

How the Idea of the Phonograph Came to Edison

Curiously enough, the idea of the phonograph came to Edison at a time when he was more interested in telegraphy than in anything else. During the summer of 1877 he had been engaged in the invention of a telegraph-repeater—a labor-saving device which was intended to record in a central office telegraph messages received from many outlying country districts, and to transmit them mechanically to their destinations at more than

human speed. The need of such an instrument was apparent. A telegraph operator could send only thirty-five or forty words a minute. If scores of messages received by a central station could be repeated by some machine at a speed of a hundred words a minute, for example, there would be an enormous saving in time, money, and labor. It was but natural that Edison, the man who had done so much to improve telegraphy, should be fascinated by the possibilities of a repeater.

The repeater with which Edison was experimenting during



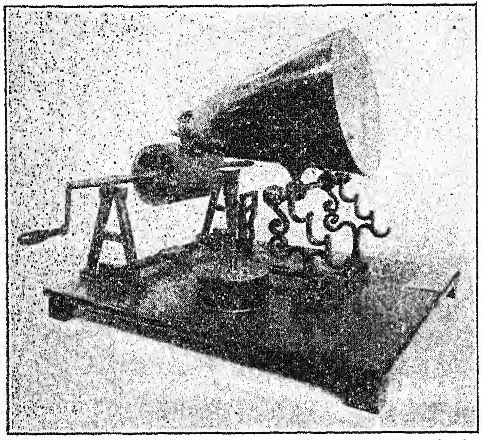
THE TELEGRAPHIC FATHER OF THE PHONOGRAPH.

This is the telegraph repeater with which Edison was experimenting at the time that the idea of the phonograph occurred to him.

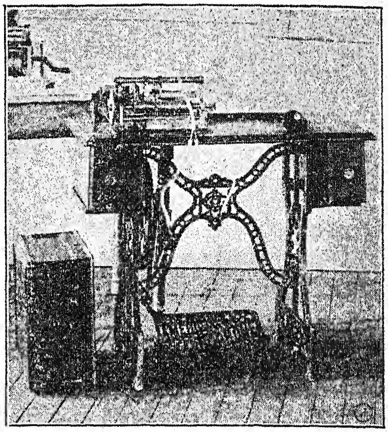
that eventful summer of 1877 bore a curious resemblance to the modern disk-phonograph. Upon a revolving metallic plate was a disk of paper; above it an electromagnet carrying an embossing point. When the electromagnet was connected with a telegraph circuit the pivoted arm of the electromagnet moved up and down, and the embossing point indented upon the revolving paper disk the dots and dashes as they came in over the telegraph line. By reversing the operation these dots and dashes could be automatically repeated over another telegraph line more rapidly or slowly. Edison tested this apparatus at varying rates of speed. When the disk turned very fast he noticed that a musical note was given out.

Why was the musical note produced? The little embossing point had been made to vibrate like a tuning-fork as it passed rapidly over the indentations. The ordinary scientific mind

would have been quite satisfied with this obvious explanation and would have passed on. But Edison's is one of the most imaginative minds of which we have any record. An ordinary occurrence is to him what the pressure on a trigger is to a loaded gun. Something like a mental trigger must have been pulled



Courtesy United States National Museum, Washington, D. C.



Courtesy Columbia Phonograph Company.

(Left) LEON SCOTT'S "PHONAUTOGRAPH" OF 1857.

This is usually regarded as a precursor of the phonograph. It had little in common with talking-machines, for it could only register sound. The sound projected against a diaphragm was recorded on a moving cylinder around which paper covered with lampblack was wrapped. A lever or stylus was attached to the diaphragm, and this stylus traced the record on the smoked paper.

(Right) THE ORIGINAL TREADLE GRAPHOPHONE OF 1887.

In this the principle of Bell and Tainter's patent was applied.

on that memorable day; for he wrote down the following observation in his note-book:

"Just tried experiment with diaphragm having an embossing point and held against paraffine paper moving rapidly. The speaking vibrations are indented nicely and there's no doubt that I shall be able to store up and reproduce automatically at any future time the human voice perfectly."

Evidently he must have shouted against the diaphragm with encouraging results.

A musical note emitted by the rapid passing of a point over indentations on a piece of paper. And from this flashes the

idea of preserving "for any future time the human voice perfectly!"

The idea preyed upon him for days. It crowded everything from his mind. It took mental shape. He could see in his mind's eye exactly how a machine would look that would first record and then reproduce the human voice. The machine must be built then and there.

Edison's First Experiments with Paraffine-Coated Strips

He knew that he must have a diaphragm of some kind. Even our ears have diaphragms, our ear-drums; for there must be something with a surface large enough upon which the puffs of air may beat that come from lips or musical instruments. He coated some strips of paper with paraffine-wax, and these coated strips he passed by hand, up and down, behind a diaphragm to the centre of which a little steel point was fastened. "Hoo, hoo, hoo!" he shouted against the diaphragm, whereupon the little point would embed itself more or less in the coating of paraffine. He reversed the motion of the coated paper slip and listened. Very faintly there came back his original "hoo, hoo." He had made the diaphragm vibrate exactly as it had done when he had shouted against it. He had made it puff the air, made it set up pressure-waves, like his own.

Paraffine was too soft. The record was easily destroyed. Perhaps some hard wax would answer. To find such a wax meant many months of patient searching and testing, and he was all aflame with eagerness to obtain immediate results. Perhaps tinfoil would do—something soft and pliable, yet more permanent than paraffine. On August 12, 1877, he made a rough drawing of a device, which was destined to be the first phonograph, and wrote upon it "Kreusi—Make this." A facsimile of this historic sketch is reproduced on page 451.

The Kruesi to whom this brief command was given was the late John Kruesi, a faithful and able instrument-maker and coworker for many years. It was Edison's custom not only to give him the precise instructions that he needed, but also to place a limit upon the amount of money that was to be spent.

In this instance Kruesi was informed that he could spend exactly eighteen dollars.

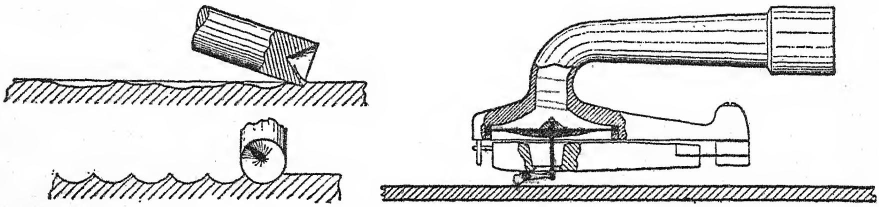
Kruesi had made many a model for Edison, but this was the queerest that he had ever been ordered to build.

"What's it for?" he asked.

"I want it to record talking," said Edison.

"It's a crazy idea," was Kruesi's comment.

Rumors of Edison's new machine spread in the laboratory. The men who worked for Edison had seen him accomplish



(Left) EDISON RECORD ENGRAVING TOOL.

After eight months' experimenting Edison made perfect sound records with a sapphire cutter (upper view), and reproduced them with another sapphire which had a ball-shaped tip (lower view).

(Right) MODERN EDISON DIAMOND-POINT REPRODUCER.

wonders, but this notion of a machine that would talk like a human being proved too much for ready acceptance. Carman, the foreman of the machine-shop, said: "I'll bet you a box of cigars that it won't work." To which Edison replied: "We'll see."

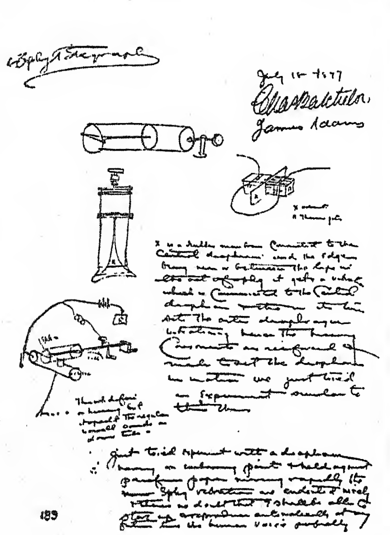
The First Trial of the Phonograph

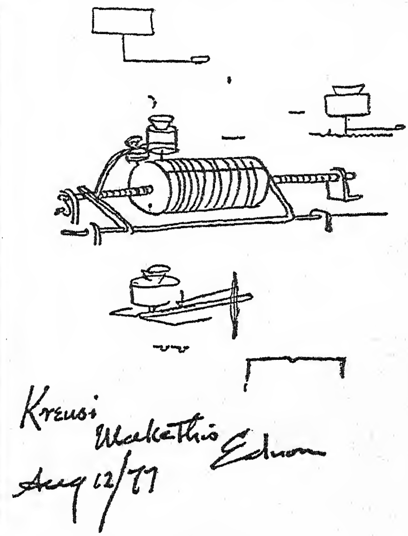
In a few days Kruesi finished his model and laid it on the table of the "old man," as Edison was even then called, although he was scarcely thirty years of age. Edison looked the model over to see if his instructions had been carried out. Kruesi stood beside him, curious and amused. He watched the "old man" turn the handle—a test of the machine's free-turning ability. He saw him take a sheet of tin-foil, wrap it around the cylinder and fasten it with a strip of lead laid in a groove cut for that purpose. By this time the entire laboratory staff had gathered around the table, watching the proceedings with ever-increasing interest and offering facetious advice.

Edison calmly proceeded to adjust the speaking mouthpiece. Then he turned the cylinder by means of the crank and shouted into the mouthpiece:

> "Mary had a little lamb,
>   Its fleece was white as snow,
> And everywhere that Mary went
>   The lamb was sure to go."

The fateful moment had arrived! Edison saw that there were indentations on the tin-foil. He expected to reproduce





(Left) EDISON'S ORIGINAL SKETCH OF THE PHONOGRAPH.

Reproduction of page of Edison's note-book in which he recorded his first conception of the phonograph.

(Right) EDISON'S FIRST WORKING DRAWING OF THE PHONOGRAPH.

Reproduction of Edison's sketch of the first phonograph with instructions to Kruesi, his modeller, to "make this."

only an encouraging fragment of a word here and there, or to obtain a few recognizable squeaks at best, something to show that at least he was on the right track. Amid the joking and laughing of his men he turned back the cylinder, adjusted the reproducing diaphragm, and once more rotated the cylinder. Back from the tin-foil came a thin, small voice:

> "Mary had a little lamb——"

Not a word was missing! The phonograph was born!

Amusement, laughter, incredulity gave place to an awe-stricken, intense silence. Then the wonder of it dawned on Kruesi and the rest. Edison himself was amazed. A new strip of tin-foil was put on the cylinder. Again, perfect reproduction.

Now the reaction set in, and the men joined hands and sang and danced around Edison. It was a memorable day—and night also—at Menlo Park Laboratory, for the entire staff stayed until dawn, taking turns at speaking, singing, laughing, and whistling into this first crude little phonograph, and listening to their own voices with childish delight and enthusiasm.

How the World Received the Phonograph

The next day Edison took the model under his arm and went over to the office of the *Scientific American*, in New York, and told the editor, Mr. Alfred E. Beach, he had something to show him. Placing the model on a table Edison put a sheet of tin-foil on the cylinder, turned the crank, and recited "Mary had a little lamb." He then adjusted the reproducer and rotated the cylinder. Again the voice and words were reproduced loud enough to be heard all over the room, to the intense amazement and awe of Mr. Beach and the bystanders who had come flocking around. Of course, there was an incessant demand for more demonstrations, and they were given until the crowd grew so great that Mr. Beach became anxious about the carrying capacity of the floor.

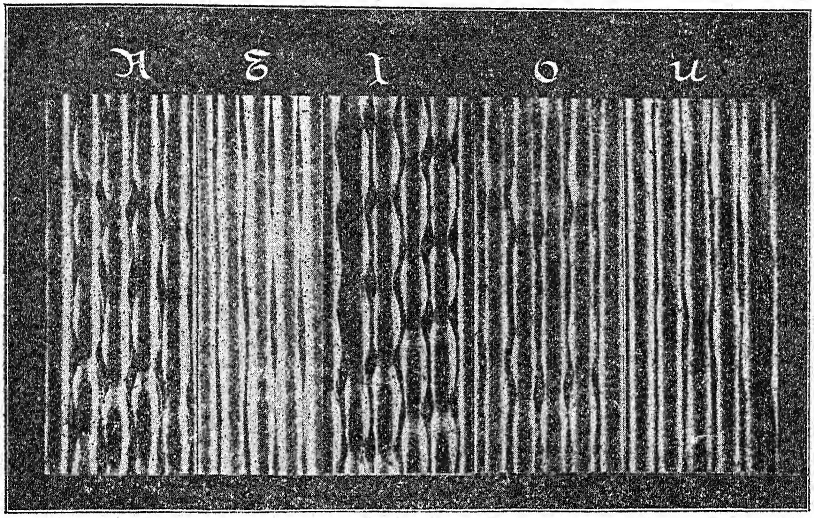
The following morning the newspapers were filled with the news of this astonishing invention, and the fame of it spread quickly throughout the world. Edison was deluged with letters, telegrams, and cables from every part of the globe. Every one wanted to see, hear, or possess this latest marvel.

So great and insistent was this demand that Edison was compelled to manufacture and sell tin-foil phonographs. He made some improvements over his first model and decided on two sizes of which he had a quantity made in the little shop of Sigmund Bergmann, a former workman who had been manufacturing some of Edison's telegraphic apparatus in New York.

These first phonographs with tin-foil records were mostly

used for exhibition throughout the country. So great was the interest aroused that vast numbers of people flocked to hear the mysterious and wonderful machine that recorded and reproduced the human voice, music, and other sounds. The royalties were large. In Boston alone $1,800 was collected in one notable week.

The wildest accounts of the phonograph were printed in both the American and European newspapers, but the palm for



A HILL-AND-DALE RECORD MAGNIFIED.

A microphotograph of a tenor voice recorded according to the Edison "hill-and-dale" method.

imaginative mendacity must be awarded to the *Figaro* of Paris. "It should be understood," said the author of that extraordinary specimen of journalism, "that Mr. Edison does not belong to himself. He is owned by the telegraph company which lodges him in a superb New York house; maintains him in luxurious style, and pays him a huge salary so as to profit by his discoveries exclusively. The company employs men who never leave Edison for a moment—at table, on the street, in the laboratory. Hence this wretched man, guarded more closely than any criminal, cannot devote a moment's thought to himself." Then followed a description of Edison's "aerophone," a

description which would have done justice to Jules Verne. "You speak to a jet of vapor," the readers were told, and "your voice is carried for a mile and a half."

France recovered its poise when the phonograph was exhibited before the Academy of Sciences on March 11, 1878, by Count du Moncel. At the request of du Moncel, Edison's French licensee, Puskas, seated himself in front of the phonograph and spoke into the mouthpiece: "The phonograph is highly honored at being presented to the Academy of Sciences." The chairman demanded silence. Puskas fitted a large pasteboard horn to the reproducer, and then, to the great astonishment of the audience, the phonograph expressed its pleasure at being introduced to the Academy in Puskas's rather nasal American-French. A member of the Academy refused to believe his eyes and ears. "There is some trickery about this," he said. "A machine can't reproduce an accent. This is simply a piece of ventriloquism." Du Moncel then took his seat at the phonograph and said in his best Parisian: "We thank Mr. Edison for having sent us his phonograph." Du Moncel's words were repeated in all their Parisian purity, and the sceptic was convinced.

Public interest in Europe and America was maintained only for about a year and a half. The phonograph with the tin-foil record was largely an exhibition machine. Its sale could be limited at best because it was not easily operated by hand. In the meantime, Edison had begun his experiments on the electric light, and did not take up the phonograph again for nine years.

Yet he realized its possibilities. In an article which he wrote for the *North American Review* for June, 1878, he thus prophesied its future:

"Among the many uses to which the phonograph will be applied are the following:

"1. Letter-writing and all kinds of dictation without the aid of a stenographer.

"2. Phonographic books, which will speak to blind people without effort on their part.

"3. The teaching of elocution.

"4. Reproduction of music.

"5. The 'Family Record'—a registry of sayings, reminiscences, etc., by members of a family in their own voices, and of the last words of dying persons.

"6. Music-boxes and toys.

"7. Clocks that should announce in articulate speech the time for going home, going to meals, etc.

"8. The preservation of languages by exact reproduction of the manner of pronouncing.

"9. Educational purposes: such as preserving the explanations made by a teacher, so that the pupil can refer to them at any moment, and spelling or other lessons placed upon the phonograph for convenience in committing to memory.

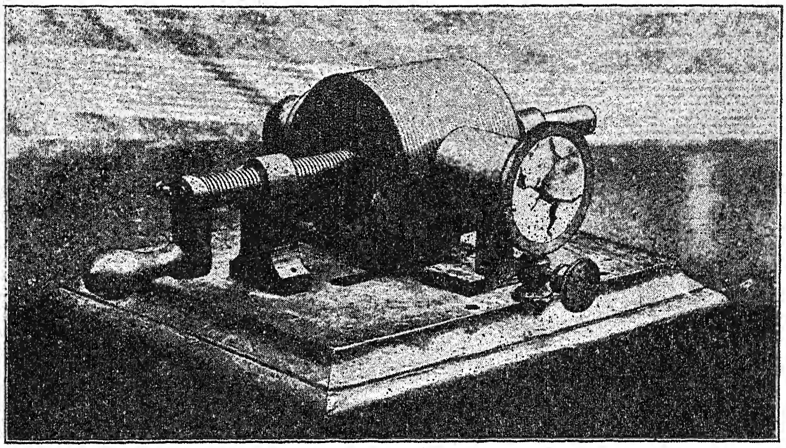
"10. Connection with the telephone, so as to make that instrument an auxiliary in the transmission of permanent and invaluable records, instead of being the recipient of momentary and fleeting communications."

Edison Resumes Work on the Phonograph

After nine years of intense application to the invention of the electric incandescent lamp and his complete system of electric light, heat, and power, Edison resumed work on the phonograph in 1887. He entirely changed the mechanism to use a cylindrical wax record, and thus created a more practical type of phonograph which could be used by every one. About this time his laboratory at West Orange, New Jersey, was completed, his plans including the building of a factory in which the improved instrument was to be manufactured in large quantities.

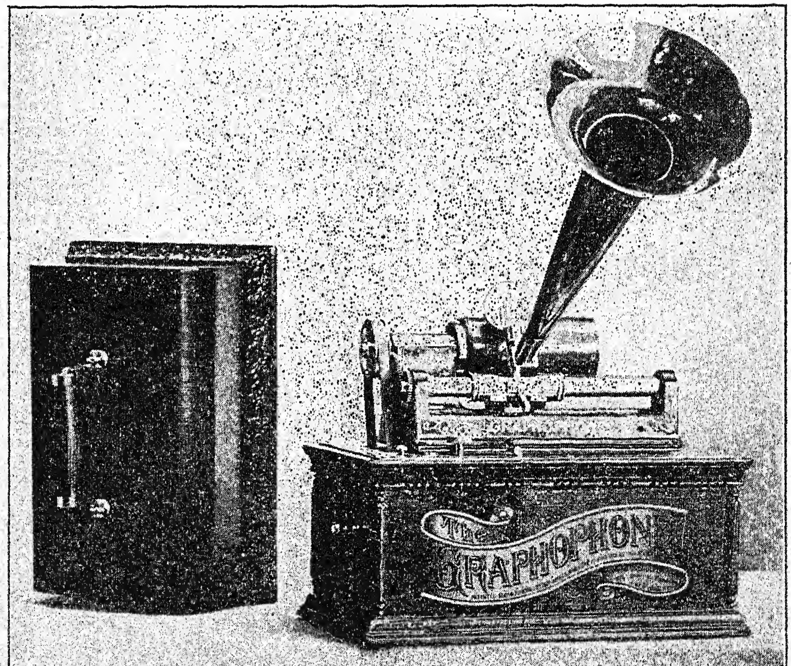
Edison realized that exact uniformity of speed is essential to record and reproduce speech and music satisfactorily, and that a hand-operated phonograph could not, therefore, become a commercial success. He invented a mechanism which could be operated mechanically at a given, regular speed.

This second type of phonograph was at first equipped with a battery-driven electric motor, which rotated the cylinder, but the electric motor was afterward superseded by a clock-spring motor of the type now used in all phonographs and talking-machines. As a material for the records, tin-foil was entirely



EDISON PHONOGRAPH OF 1888.

This was the type of machine which was first bought by the public. The hand-turned crank soon gave way first to an electric motor, and then to a spring-motor of the type now used.



Photograph by Columbia Graphophone Company.

THE GRAPHOPHONE OF THE NINETIES.

abandoned, and in its place a cylinder of wax, or wax-like material, was decided upon.

In the early stages of development Edison experimented with paper cylinders covered with paraffin or other wax-like materials. Here, however, he found himself following in the footsteps of two other inventors, Chichester A. Bell and Charles Sumner Tainter, two Washington men who had been working on the phonograph during the time that Edison was so intensely busy with his electric light. A patent had been issued to Bell and Tainter on a cylindrical record blank made of paper coated with certain combinations of wax, and they had also patented various other improvements.

About this time a corporation called The American Graphophone Company was formed by some Philadelphia capitalists to exploit the Bell and Tainter patents. This company equipped a factory and entered upon the manufacture of talking-machines and of wax-covered paper-cylinder records.

Edison's exhaustive experiments with wax-covered paper cylinders had convinced him that the waxy material must be comparatively hard. But here he encountered a difficulty. If the paper cylinder was coated with hard wax it would not expand and contract, as the temperature of a room rose or fell, at the same rate as the paper cylinder itself. Either the paper cylinder would warp or the wax coating would crack. Therefore, he abandoned this plan and came to the conclusion that a cylinder must be made entirely of wax.

The Development of the Wax Record

To this end he instituted a long series of experiments in the development of a perfect all-wax cylinder. At one time he did not leave his laboratory for five days and nights. His laboratory note-books of this period disclose the vast amount of work that he did in making up and testing innumerable combinations of waxy materials obtained from all parts of the world. Progress was slow but sure. Difficulties were eliminated one by one, and gradually a successful all-wax record blank was evolved.

There were other problems to be solved. The record on wax was gouged out by a small metal chisel fixed to the dia-

phragm, and the reproducer was equipped with a similar chisel. The chisel proved to be unsatisfactory. After having been reproduced a few times, records were practically unintelligible, because parts of the sound-waves were cut away. Moreover, the chisel could not satisfactorily record or reproduce hissing sounds, such as words in which the letter "s" appeared. Edison determined to remedy the defect, and began the most patient and persistent series of experiments that he ever conducted. For eight long months he experimented in thousands of ways, to record and reproduce such words as "sugar," "scissors," "specie," etc., and, at last, succeeded. At the same time he obtained perfect articulation.

The new method of recording depended on the utilization of a minute and peculiarly shaped sapphire for engraving sound vibration in a groove of the wax cylinder. Another sapphire served for reproduction, but a sapphire which had a ball-shaped tip so that it could not cut the record. The recording tool is shown on page 450 in profile and end-on views respectively.

The Attempt to Use the Phonograph for Dictation

During this period a corporation called the North American Phonograph Company had been formed by Philadelphia capitalists who aimed to exploit the phonograph for general business dictation. After having vainly tried to introduce wax-coated paper cylinders, made in accordance with the Bell and Tainter patents, the company negotiated with Edison for the right to use his all-wax cylinders. Edison received a large sum for his rights.

The phonograph at that time did not possess the necessary refinement to take the place of a stenographer. The company's predestined failure was hastened by the death of its chief promoter, and Edison, being the principal creditor, took back his phonograph patents. He founded the National Phonograph Company, and decided to concentrate his energies on the recording and reproduction of music. He reorganized his factories, equipped them with new machinery and tools, and proceeded to exploit a field in which he has ever since occupied a prominent position.

It was impossible to think of selling original records to the

public. One such record made by a first-class artist might cost several hundred dollars, even in that day. Clearly, some method had to be invented of duplicating the original precious record—some method comparable with printing a newspaper from type.

Duplicating the Original or Master Record

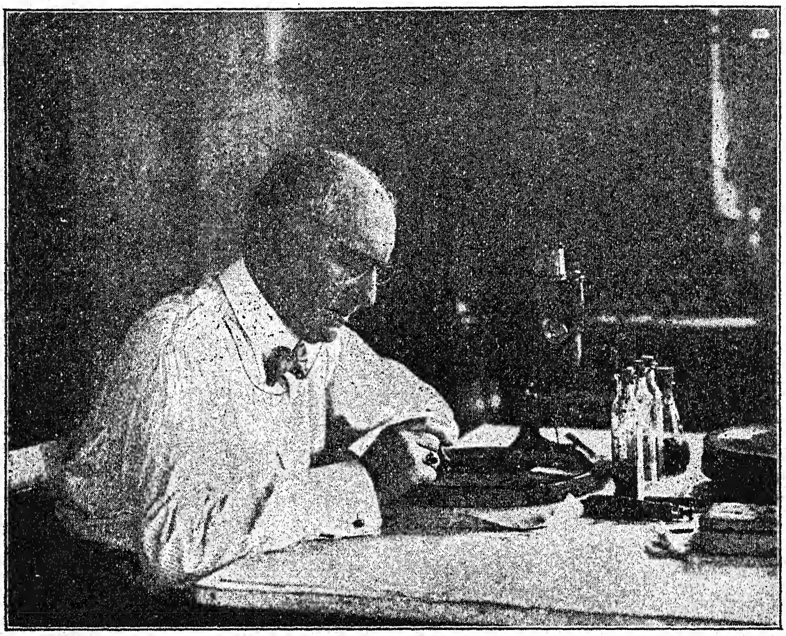
This problem presented great difficulties, for the sound-waves cut in the surface of the wax were only about one-thousandth of an inch deep, or about the thickness of tissue-paper. The millions of infinitesimal waves in a record must be duplicated so as to be microscopically identical with their originals and be free from false vibrations and other defects. Obviously, wax duplicates could not be made from a wax original or "master." So it became necessary to discover other means. After a vast amount of experiment, Edison succeeded in electroplating a metallic "submaster," or matrix, from the original. Into this matrix melted wax was poured. The resultant wax-casting was an exact duplicate of the original.

Even more remarkable was another method of duplicating the original or "master." In a chamber from which the air was exhausted, Edison revolved the "master" between two leaves of gold, which was electrically vaporized. The gold vapor was deposited on the wax master in the form of a film about one eight-hundred-thousandth of an inch thick. It would take 800 such films to form a pile as thick as a sheet of the finest tissue-paper. Upon such a gold film a heavy backing of baser metal was electroplated, and thus a substantial mould or matrix was made.

The second type of phonograph with wax-cylinder records carrying music was brought out about 1888, and found a music-hungry world awaiting it. Up to that time the phonograph could not be purchased by the general public. Comparatively few people had ever seen or heard it; for the old tin-foil instrument had been used only for exhibition. The factories were humming day and night for years to fill the great demand for the improved machine.

The Invention of the Disk Record

Emile Berliner, a German who had emigrated to this country and who played a conspicuous part in the development of the telephone, devised a method of making records which was somewhat different from Edison's and which depended on the use of disks. Edison made his sound records by causing the en-

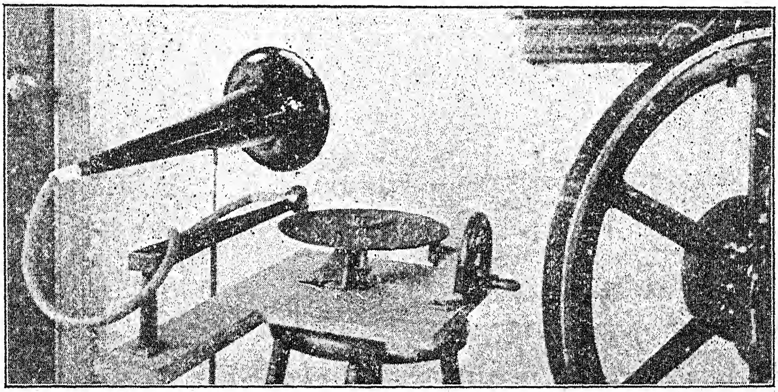


EMILE BERLINER, INVENTOR OF THE "LATERAL-CUT" DISK.

graving tool to rise and fall, for which reason his method is technically known as the "hill-and-dale." Berliner, on the other hand, thought it would be better to cause the tool to swing from side to side in the groove, for which reason a disk was more serviceable than a cylinder. Because the tool is moved from side to side, Berliner records are called "lateral-cut." Berliner's way of making the master record was also different. Instead of using an all-wax plate he employed a disk of zinc, covered with wax. The music was recorded on this wax surface, characteristic indentations being made, and then acid

was applied which etched the record on the zinc, thus making a metallic "master" from which impressions could be taken.

The results, so far as the reproduction was concerned, were good but not perfect. After experimenting for some time Berliner felt that he needed the help of a more expert mechanic than himself. He took his machine and records to a little machine-shop in Camden, New Jersey, owned and operated by



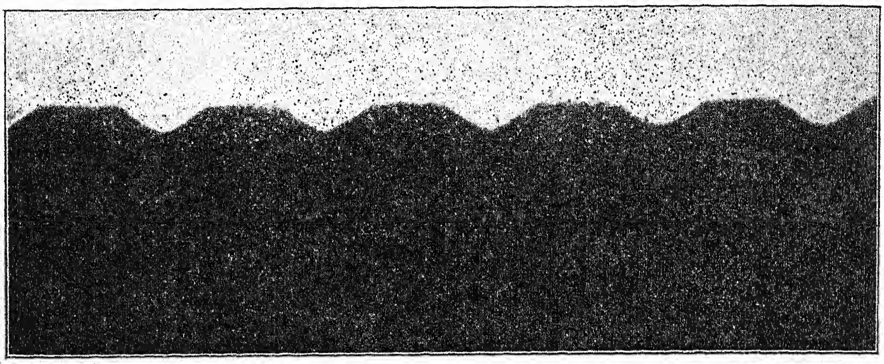
FIRST PUBLICLY EXHIBITED GRAMOPHONE OF EMILE BERLINER.

The original was first exhibited in the Franklin Institute, May 16, 1888, and is now in the National Museum, Washington, D. C.

Eldridge R. Johnson, and left them there for certain repairs and changes to be made. After he had left the shop Johnson made a study of the device and soon realized its great possibilities. The further he progressed with his study, the more enthusiastic he became. He joined forces with Berliner. Together they proceeded to make the needed improvements and refinements in the machine and records until at last they had completed a model of the familiar disk type of talking-machine. This was the beginning of the Victor Talking Machine Company, of which Mr. Johnson is the president, and has been the directing spirit to this day.

These events occurred about 1896 or 1897. In the meanwhile, Edison had sold upward of one and a half million cylinder phonographs and more than a hundred million of the cylindrical records. Although he had no difficulty in selling

cylinders, the demand for disks was insistent, probably because of the records which many great artists had made on disks. Accordingly, about 1907 or 1908 he began a series of experiments which were to end in the production of a "hill-and-dale" disk record; for to the hill-and-dale method of recording Edison had been wedded from the beginning. His earliest patents had been granted for disk records, and he was but reverting to orig-



From a photograph by Columbia Graphophone Co.

MICROPHOTOGRAPH OF A "LATERAL-CUT" RECORD.

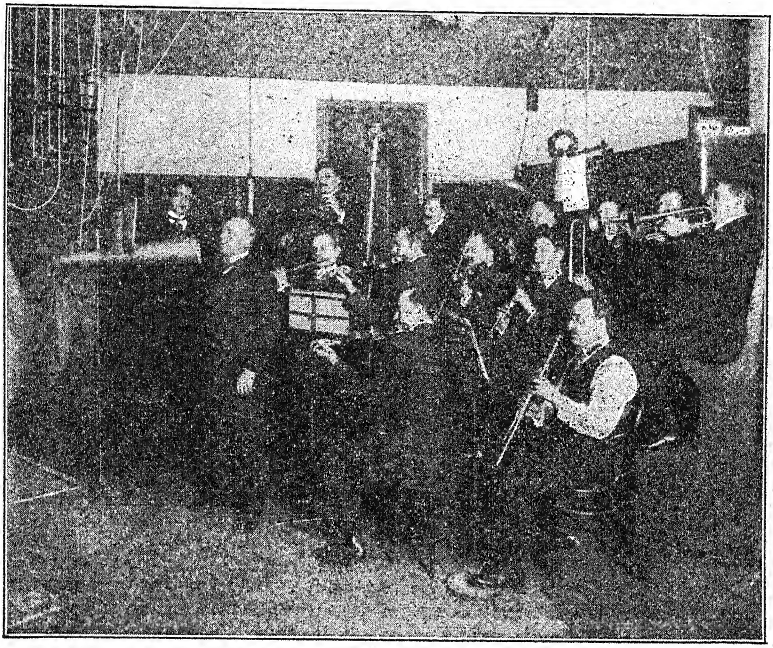
inal ideas. After an immense amount of experiment his disk phonograph was completed and put on the market.

How Records Are Made for the Public

Although the principle of the phonograph is now well known, the art of making records is deliberately shrouded in mystery. The particular composition of the wax-like "master" employed by a manufacturer is kept a profound secret. Few "outsiders" are permitted to see even the making of a record—certainly no one connected with a rival company. The proceeding is complex and calls for much skill, technical knowledge, and experience.

Imagine a great tenor, a popular operatic idol, about to immortalize his rendering of Verdi's "Celeste Aïda." Before him is the mouth of a horn; behind him the orchestra. Even he does not see the actual recording equipment; for the small end of the horn is located either behind a curtain or a partition. The musicians are poised between heaven and earth, for some of them sit on shelf-like benches, so that their heads are not far

from the ceiling. So cramped are the quarters that often they assume positions at which a concert audience would gasp in amazement. For example, the trombonists sometimes turn their backs to the conductor; they follow him by keeping their eyes glued on mirrors by which his expressive beating of time is reflected. The loud instruments—the ponderous brasses—



MAKING A PHONOGRAPH RECORD.

are always placed in the rear so that their metallic blare may not drown out the finer tone of the strings, which are always to be found in front. The tenor soars up and down the scale directly into the yawning mouth of the horn. He gives his full-throated best; for he knows not only that his rendition of "Celeste Aïda" will be heard by thousands, perhaps by millions, but that the luscious top notes, upon which his reputation hangs, will be compared with the equally luscious top notes of other tenors who have sung "Celeste Aïda" into the phonograph before him, and who will sing it into a recording-horn years after he is dead. A mistake—and the record must be

made over again. Therein the tenor has an advantage denied him when he appears in public. The purchasers of his record never know that he may have tried more than once to produce just the effect that he had in mind when he sang a particularly soul-stirring phrase.

The original record thus made, the "wax-master," is turned

Courtesy Columbia Graphophone Company.

THE PHONOGRAPH IN THE OFFICE.

Although Edison very early predicted that the phonograph would supplant the stenographer in business, it was not until late in its development that the instrument was widely introduced in offices. Here a modern dictating graphophone is shown. The machine is ready at any time to record anything from a fleeting idea to a business letter.

over to the factory to be duplicated a thousandfold, even a millionfold.

Thus "Celeste Aïda" or the latest dance music reaches the backwoodsman or the Fifth Avenue mansion. Trills, roulades, scales, disembodied from a perishable personality, countless million puffs of air have been solidified, so that they can be transported to Alaska or Zanzibar. It seems like a miracle even now, when the strains of music made in some American seaboard town are heard all over the world, when mere recorded sound is as much an article of commerce as a barrel of sugar.

PART III

POWER

CHAPTER I

PUTTING STEAM TO WORK

HISTORIANS tell us that the average freeman of ancient Greece had five slaves or "helots." They were the machines of Greece. Engineers have estimated that every American has thirty slaves working for him, thirty tireless slave-machines that never rebel at the hopelessness of their lot and that feel nothing of the wear and tear of their slavery. Because the Greek slaves were only human, with human shortcomings, the best flour-mill in Athens, in the time of Pericles, produced but two barrels of flour a day. With slave-machines, a single Minneapolis mill of our time produces in a day 17,000 barrels of flour. There were no helots in the Europe emancipated by the French Revolution, but there was just as much hard, back-breaking labor in the towns as ever there was in old Athens. Before the slave-machines were invented a skilled English workman, during the early part of the last century, could make thirty needles a day. Now a girl, mistress of a slave-machine, produces 500,000 needles a day, and has little to do but watch the slave-machine cut, sharpen, and perforate the needles.

If this is the age of the slave-machine the steam-engine has made it so. Before the invention of the steam-engine, Europe and America had few machines and few factories, certainly no factories of the kind that now belch smoke from a thousand cities. Until the coming of the steam-engine it mattered little whether a country possessed coal deposits. Now nations bargain for coal and are even willing to fight for it. Coal means power, industry, and wealth; two hundred years ago, it meant simply fuel to be burned on the hearth. Because of the steam-engine, Great Britain became the world-dominating commercial nation that she is to-day. Fuel is her life-blood. It is also the life-blood of the United States; for even our waterfalls, numerous as they are, could not supply us with the power we now require if they were all harnessed.

It is difficult to think of the world as it was before the steam-engine. There were no railways, no steamships, no great blast-furnaces where steel is made, no cheap clothes, no electric lights, no machines to till the soil and reap the enormous harvests. Life was only outwardly different from what it was in the days of Julius Cæsar. Greeks and Romans travelled either on wheels or on horseback or in sailing vessels; a method of locomotion which, well into the nineteenth century, had not greatly been improved upon by Englishmen, Frenchmen, or Americans. The Greek and Roman farmer did his own spinning and weaving, forged his own tools, and with his own hands made everything he needed; so did the European and American farmer up to the introduction of the steam-engine.

Steam proved the great liberator of mankind. Before we learned how to use steam, human energy was exploited for thousands of years. The steam-engine enabled men to use the energy locked up in coal, thereby releasing from drudgery, bondage, and misery an army of workmen who, if politically better off than the Greek helots, toiled as long and as hard. Eight hours is the accepted working-day now, but that working-day would be almost unthinkable without steam-driven, labor-saving machines. Brain is doing more work than brawn. Machines have lightened human labor and given men time to think.

When at last the steam-engine made it possible to use the energy in fuel, invention flourished as never before. Power was given to the world. At once a thousand opportunities of using power suggested themselves. Then it was that the slave-machines were invented; machines that were nothing but steel fingers, hands, fists, and arms; machines hundreds of times stronger, faster, and surer than human hands and arms; machines that would strike a blow more powerful than a hammer wielded by a Hercules, dig up tons of earth at a single scoop, whisk material from place to place in the twinkling of an eye, and fashion wood and metal for a million purposes with never-failing, uncanny skill.

The steam-engine made the coal-owning countries industrially and even politically great, and made their people machine-inventors, machine-users. It follows, almost as a matter of course, that because the United States is the largest coal-owning

country, the steam-engine proved enormously important in its development; and, in truth, not until the steam-engine was introduced, not until American coal could be converted into energy in American factories, not until American inventors had steam at their command to operate the many machines that they had devised, did the United States take its place in the front rank of great industrial nations.

Not one of the remarkable men to whom we owe the steam-engine could have foreseen how their inventions would change the drift of civilization. They built castles in the air, as inventors do, but their castles were hovels compared with the magnificent structure reared on the foundation of their discoveries. They thought only of meeting the needs of the moment. And, in the beginning, these needs were merely the pumping of water out of coal-mines.

England's Need of a Pump to Keep Mines Dry

Long before Columbus discovered America, Englishmen mined coal. They dug with picks and shovels what coal they found at the surface, and when that was burned they dug deeper and deeper. Englishmen still speak of coal-mines as "pits"; the word comes down from a time when great holes had to be made to reach the coal. When the holes could be dug no deeper, it became necessary to sink shafts—holes with more or less straight sides. Dig a hole or a shaft, and sooner or later a spring is struck and water bubbles up. The pump, a very old invention, had to be applied to draw up the water so that the miners could work. Sometimes the pumps were driven by hand, but more often by horses. They were crude pumps, so crude that they drew up but little water, and that at great expense in money and in man or animal power. England's forests had been hewn into for both wood and charcoal. Even before Queen Elizabeth's time it had become necessary to pass laws for the protection of timber. England's plight was, therefore, desperate. Unable to obtain wood enough, confronted with the difficulty of mining coal for lack of adequate pumps, it seemed as if England could save herself only by importing from abroad the fuel that could not be obtained at home. By the end of the seventeenth century mine after mine

had to be abandoned because the water rose faster than the pumps could draw it up.

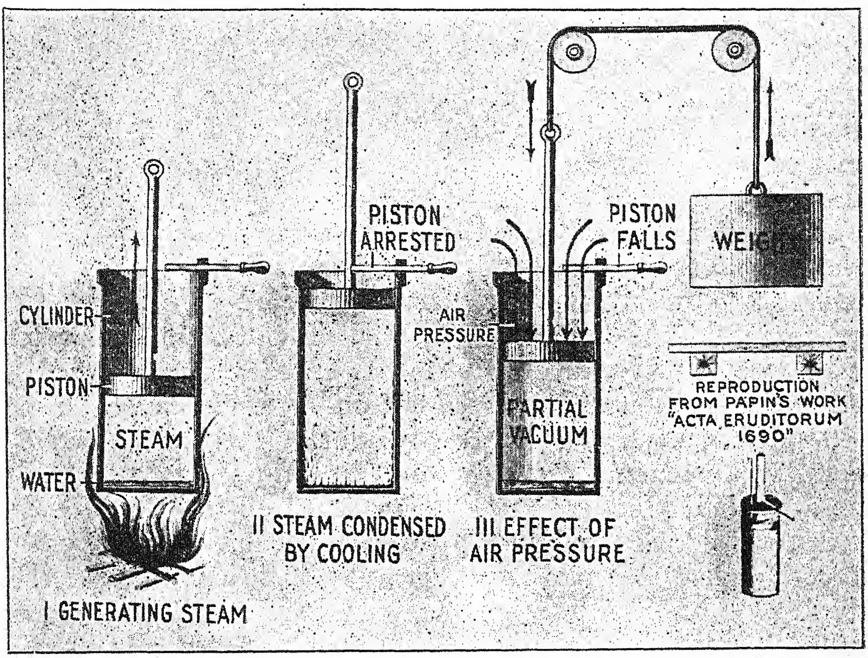
What England needed was a pump that would draw water as fast as it welled up. The first genius who saw the opportunity but who could not make the most of it, was an impractical schemer and dreamer. He was nimble-witted, restless, attractive Denis Papin, a French physicist, born about 1647, a man who had more ideas than he could possibly carry out in a life-time, and who rarely finished anything that he began. He invented a method of cooking at temperatures higher than that of boiling water; the safety-valve; a dozen different air-pumps and devices for raising water; and he also wrote about the possibility of travelling in carriages driven by steam. Not much is known about him. His was a roving spirit. When he tired of Paris he went to London, and when he wearied of London he betook himself to Italy or Germany.

Papin Shows How Steam Can Create a Vacuum

About 1670, when Papin was living as a young man in Paris, the great Dutch mathematician and mechanician, Christiaan Huygens, who lectured there at the time, made him his assistant. Huygens was experimenting with the air-pump, and clever, imaginative Papin was just the man he needed to help him. These experiments of Huygens gave Papin the idea of pumping water in many ingenious but not very practical ways; for there is not much difference between an air-pump and a water-pump.

In those days the air-pump was discussed as eagerly as we now discuss radium or the latest invention. Scientists marvelled at the air-pump. For generations they had been taught that "nature abhors a vacuum," and that for this reason water was sucked up as the piston was pulled out of a common syringe —the oldest and simplest form of water-pump. The vacuum-pump taught them that the air we breathe has weight, that it presses on everything around us, ourselves included, because it has weight, and that when the piston of a syringe is pulled out water rushes up simply because the pressure of the heavy outer air forces it into the empty barrel of the syringe. Scientists began to measure the air to ascertain its weight. Samuel Pepys

in his diary states that Charles the Second once attended a meeting of the Royal Society and laughed uproariously at the silly members "for spending time only in weighing of air and doing nothing else since they sat." This helps to explain why Charles was popularly called the "merry monarch." Perhaps



Courtesy Deutsches Museum.

HOW PAPIN CREATED A VACUUM BY CONDENSING STEAM.

Papin, in 1690, proposed a thin, open-topped cylinder fitted with a piston provided with a rod on which was a latch. Water in the cylinder was externally heated and steam generated to force the piston up where it was retained by the latch. When the fire was removed the steam condensed so that the piston fell with such force as to enable it by an attached rope to lift a weight.

he would not have laughed so heartily if he could have known that out of these early air-weighing experiments, conducted by earnest scientists in several countries, would come ways of giving men machines to do their hardest work, of curing their diseases, and of making life easier and happier.

Now Papin knew just how an air-pump worked—knew that the air pressed on everything around us and that its pressure served to explain why water is forced up into an ordinary hand-

pump. It has never been possible to obtain a perfect vacuum; it was still less possible in Papin's day. Like his master Huygens and many others, Papin was always trying to obtain a better vacuum. In 1687, he turned up in London with a new, startling method, and showed the scientific men of the day a device in which steam produced the vacuum.

The apparatus was simple enough; merely an ordinary upright cylinder in which a piston could rise and fall. Papin placed a little water in the cylinder and heated it with an outside flame, just as he would a kettle. The water boiled away into steam, and the expanding steam forced the piston up and drove out the air through a hole in the piston. Papin then took away the flame, closed the hole in the piston, and allowed the hot cylinder to cool off. Soon the steam condensed, which meant that it shrank back again into water. There was little or no air in the cylinder, only a little water at the bottom. The outer air or atmosphere, by its sheer weight, pressed the unresisting piston down to the bottom of the cylinder.

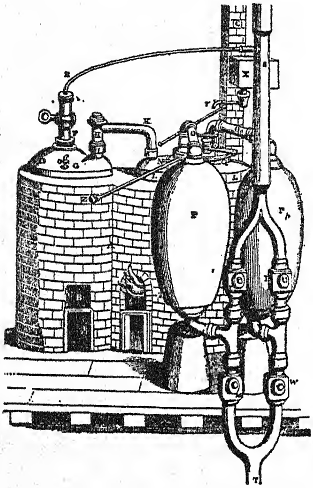
Papin talked and wrote about the possibilities of thus creating a vacuum by mere steam, but did nothing more. Two hard-headed, practical Englishmen heard about his method of producing a vacuum, and it set them thinking of England's flooded coal-mines and of a machine which would pump them dry. One of these Englishmen was Thomas Savery, and the other, Thomas Newcomen; they became friends and partners in business. Their names were so identified with the invention and introduction of the first useful steam-engine that in the old books the one is rarely mentioned without the other.

How Savery Applied Papin's Principle

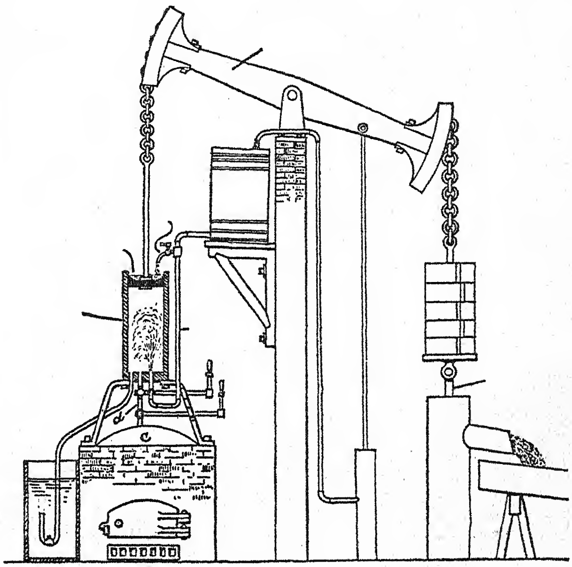
Very little is known about Thomas Savery beyond the fact that he was a military engineer, that he had a mechanical turn of mind, and that he was called "Captain" Savery, although he was never a captain of anything. He is first heard of in 1698, because in that year he received a patent for what he called a "fire-engine."

Savery's "fire-engine" was the first practical steam-pump or steam-engine ever invented. It had a vessel into which steam was admitted by a pipe from a boiler to drive out the air. When

the air was driven out of the vessel the steam was shut off. Savery then poured cold water over his steam-filled vessel. The steam condensed. Hence a vacuum was created: Papin's principle. Savery then opened a pipe leading to the water that was to be raised. At once water rushed into the vacuum, forced up by the sheer weight of the atmosphere. The water-



SAVERY'S ENGINE.



NEWCOMEN'S ENGINE.

valve was now shut off and the steam turned on again to drive the water out of the vessel. So, the vessel was alternately filled with steam, cooled to condense the steam and produce a vacuum, and filled with water forced up by air-pressure. Savery used two vessels and worked them alternately. Note that Savery's pump had no piston and that he pushed the water out of a vessel by the direct pressure of the steam. His process must have been very slow; but he showed how Papin's discovery might be applied to raise water.

Savery explained his steam-engine to mine-owners. They saw it actually pumping water on large estates, but its performance did not convince them that it could pump water out of a

mine. It is said that only one mine-owner bought a Savery engine. High steam-pressure was necessary; as much as 150 pounds to the square inch. Savery did not use safety-valves; hence some of his engines blew up. Perhaps the mine-owners had heard of these explosions and thought it best to keep on using horse-driven pumps.

Newcomen Also Applies Papin's Principle

Thomas Newcomen, about whom few personal facts are known, was born in 1663 and died in 1729. Newcomen was either an ironmonger or a blacksmith, and he conceived the idea of creating a vacuum in much the same way as did Savery, though his engine was much more practical. He also used steam and not air to force water directly into and out of a vessel, but it was utilized to operate a pump-handle not very different from that still to be found in many a country kitchen. His cylinder or vessel contained a piston, like Papin's. Newcomen first drove out all the air in his vessel or cylinder by steam, and then shut off the steam; then he let water spray over the hot cylinder; both ideas were taken from Savery. The steam condensed or shrank back into water. Thus a vacuum was created within the cylinder, whereupon the outer air pressed the piston down. This piston was connected with one end of a walking-beam, the other end of the walking-beam being connected with a pump-rod. The weight of the pump-rod pulled the piston up. Atmospheric pressure forced it down after the vacuum was created. So the walking-beam would rock and work the pump-rod and draw up water. By opening and closing the valves at the right time the pump was kept in operation.

One day Newcomen noticed that the engine was working better than usual. He investigated and found that water had leaked directly into the cylinder during the condensing period. At once he saw what had happened. The water did not have to cool first the hot cylinder and then the steam; it could cool and condense the steam directly. After that he always sprayed water into and not on the cylinder.

When Newcomen began to think of selling his engines to mine-owners, he met an obstacle in the form of Savery's patent.

Like a sensible man he proposed a partnership, and Savery readily agreed to the proposal. Probably Savery was glad enough to make the agreement; the mine-owners would have none of his "fire-engine," and the one developed by his partner was clearly more practical. Besides, Newcomen's engine did not work with high-pressure steam that might blow up a boiler, but with steam at a pressure a little greater than that of the atmosphere itself, which is slightly less than fifteen pounds to the square inch at sea-level. Savery's engine had to work in the mine itself within a distance of twenty-six feet of the water; Newcomen's could be erected at the mouth of the mine.

The partnership of Savery and Newcomen was successful almost from the beginning. The first Newcomen engine was installed in 1711. It proved so successful that in a few years Newcomen engines were to be found in nearly every mine in England. The invention restored wealth to dozens of mine-owners who had given up their mines as lost, and saved others from ruin. We are apt to belittle it now because it seems almost ridiculously crude in these days of wonderful machines, but it was one of the greatest achievements of human ingenuity.

Like all inventors, Newcomen had his rivals and opponents who set out to appropriate his ideas and criticise his work. One of these was Desaguliers, who published a book in 1744, entitled *Experimental Philosophy*, and in this Newcomen's engine was brushed aside as of no great importance. It was Desaguliers who spread abroad the story that Humphrey Potter, a boy whose duty it was to control the steam and water by hand, hit on the idea of opening and closing the valves of a Newcomen engine by the simple expedient of strings worked from the beam. Thus the beam, as it rocked, automatically opened and closed the valves at the right time. Such a contrivance we now call a "valve gear." It takes more than ordinary engineering ability to design a valve gear which will work in the right way, and it is not likely that a boy possessed that ingenuity. A picture of a "self-acting" engine, built by Newcomen in 1712, has come down to our time. It clearly indicates an automatic method of opening and closing the valves. Desaguliers' story may be attributed either to malice or ignorance.

Papin Hears of Savery's Success

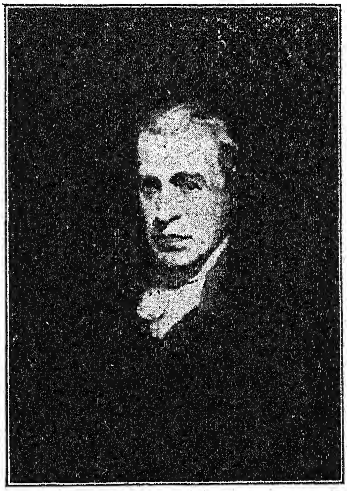
Leibnitz, the great German philosopher, used to write now and then to Papin, then living in Cassel, Germany. In one of his letters, written in 1705, he told Papin of the wonderful success of Savery, and sent him a picture of the original Savery engine—the one which the mine-owners of England could not be induced to use, but which had proved useful on large country estates. It is easy enough to imagine Papin's emotions. What a chance he had lost! He knew that Savery's principle of creating a vacuum by chilling steam in a cylinder was nothing but the practical application of his own idea. He now had nothing to show for a whole life frittered away in experimenting first with this type of vacuum-pump and then with that. Perhaps it was envy, perhaps regret, perhaps the natural bent of his active mind that prompted him to design an improvement on Savery's engine. At all events, he made some unimportant changes in it, and showed how the water that it pumped might be used to drive a water-wheel. He failed to realize that his first piston-engine might still be developed into something highly practical; instead, he took up the Englishman's abandoned pump. Following his usual practice, Papin was quite content with talking and writing about his perfection of that engine, and proceeded at once to construct a man-driven paddle-wheel boat, in which he hoped to reach the mouth of the river Weser on his way to London. The boatmen at Münden took his boat from him, claiming that he had infringed their time-honored, exclusive privilege of navigating the river, and left him with so few belongings that, when he finally reached London, he was penniless. The Royal Society gave him some money, but he died in total obscurity, in 1712, just after the first Newcomen engine, embodying his piston and operating on his vacuum principle, had demonstrated its tremendous possibilities.

James Watt's Introduction to the Steam-Engine

For about seventy years the engines of Newcomen and Savery, unchanged in principle, improved but slightly in proportions, pumped water out of English coal-mines. Then,

suddenly, the steam-engine became more than a pump; it became a machine that moved the wheels of industry and revolutionized the whole art of manufacturing.

This sudden conversion of the engine was brought about by James Watt, an instrument-maker by trade, but a real scientist by inclination and self-education. No single man in history did so much to change civilization. With him begins the modern industrial era, the era of the factory, the era of machine-made conveniences. Because of his engine Watt must be regarded as one of the world's great figures.



Courtesy W. and T. Avery, Ltd., London.

(Left) MATTHEW BOULTON.

Matthew Boulton was James Watt's partner, financial manager, and disciplinarian. Without him Watt would hardly have been able to perfect the steam-engine.

(Right) JAMES WATT, INVENTOR OF THE SEPARATE CONDENSER FOR STEAM-ENGINES.

James Watt, a Scotchman, was born in 1736. He plied his trade of instrument-maker first in London and then in Glasgow. He had not served a full term of apprenticeship, and therefore could not be admitted as a member of a Glasgow guild; the equivalent of a modern union. Since he was unable to earn his living in the city itself, the university granted him permission to open a shop on its grounds, and appointed him its in-

strument-maker. One day a professor of the university gave Watt a classroom model of Newcomen's engine to repair. As any good mechanic would have done, he soon performed the task.

But James Watt was something more than a skilful mechanic; he was a thinker, a man with a scientific mind that did not rest until it found out the why and the wherefore of things. When he had repaired the damage he put water in the boiler and started the engine. In a few minutes the water in the boiler had vanished; the engine had consumed it all in the form of steam. Watt was astonished. The engine consumed steam faster than the little boiler could supply it. It might be that the men who built Newcomen engines had also been astonished at the steam consumption of their engines; if so they certainly never bothered themselves much about it; probably they simply accepted the fact as something from which there was no escape. Watt, however, investigated. He found that the steam condensed against the cold walls of the cylinder. When fresh steam was turned on it had first to warm the cylinder again, and in the process more of it was condensed. Clearly, the cylinder must always be kept hot, so that as little steam as possible would be chilled into water and the cylinder would not have to be warmed again by incoming steam after each stroke of the piston. But how? Watt pondered over this question for weeks.

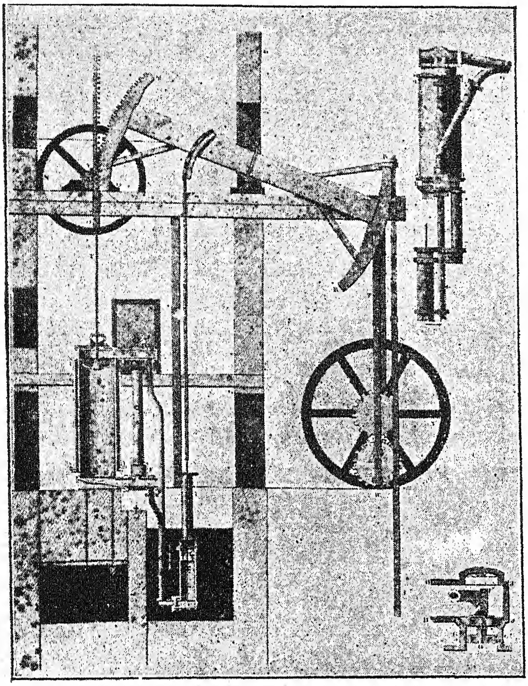
One day, as he was walking in the university grounds, the idea flashed upon him. Why not condense the steam in a *separate* condenser, connected with the cylinder by a short pipe? That ought to make it unnecessary first to cool the cylinder in order to condense the steam, and then to warm it again with new steam.

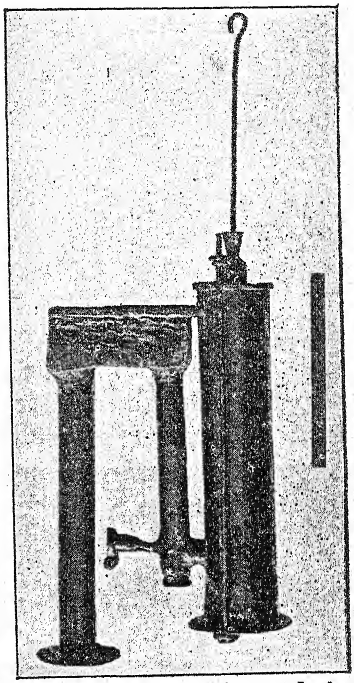
Watt Invents the Separate Condenser

He constructed a model in which this idea was carried out. What a wonderful, tense moment it must have been when he opened the valve between the condenser and the cylinder! He saw the piston forced down by the pressure of the outer air. The separate condenser worked just as he had imagined it would.

Watt might have stopped then and there and still have gone down in history as a great inventor. But he went farther.

He was so concerned with keeping the cylinder hot and the condenser cool that he made improvement after improvement. He actually placed his cylinder within a larger one and filled the space between with steam, thus inventing what we call the





Courtesy W. and T. Avery, Ltd., London. *Courtesy South Kensington Museum, London.*

(Left) EARLY WATT ENGINE WITH SEPARATE CONDENSER.

Drawing probably made under Watt's direction.

(Right) ORIGINAL EXPERIMENTAL MODEL OF THE SEPARATE CONDENSER MADE BY WATT IN 1765.

Watt was struck by the enormous steam consumption of Newcomen's pump, which was due to the fact that the steam condensed against the cold walls of the cylinder. When fresh steam was turned on, it had first to warm the cylinder again, and in the process more of it was condensed. Watt thereupon conceived the idea of condensing the steam in a separate vessel connected with the cylinder by a short pipe.

steam-jacket, and making it difficult for the cylinder to cool even by exposure to the air. Moreover, he placed his condenser in a pit filled with cold water, so that it would condense the inrushing steam quickly and not become warm itself. These accomplishments inspired Watt to perform other experi-

ments. The cylinder of Newcomen's engine was open at the top. Watt gave it a cover or "head," through which the piston-rod passed. This enabled him to force the piston down by steam from his boiler, instead of by the pressure of the outer air. Step by step he developed a real steam-engine, a vast improvement on the engine in which the weight of the air pushed the piston.

All these points Watt covered in his first patent, taken out in 1769. He demonstrated them by the use of small models constructed mostly by himself. Too poor to assume the cost of a large engine, he finally persuaded John Roebuck, proprietor of the Carron Iron Works, to go into partnership with him, by offering him two-thirds of all profits. An engine was partly built; but there were many difficulties to be overcome in construction, particularly the construction of large cylinders of even bore; for in that day there were no accurate iron lathes. Roebuck's affairs became involved, and work had to be suspended before this engine was ever put to use.

Partly through financing Watt's steam-engine, Roebuck finally became a bankrupt, and in settling his affairs not one of his creditors considered the invention which had brought about his ruin worth a farthing. Had they only known! Here was an invention worth all the money in England, an invention destined to revolutionize humanity. Instead, they held it of so little worth that Watt was permitted to retain his rights.

The Partnership of Boulton and Watt

Watt became so discouraged with the difficulty of obtaining properly bored cylinders that for a time he had to abandon the steam-engine. He was now reduced to poverty, and finding it difficult to borrow more money for his invention, he was compelled to seek employment to provide for his family. Then, as good luck would have it, he met Matthew Boulton, a strong-minded man with a good business head, and wealthy. Boulton was so impressed with the value of the invention that he readily supplied the necessary capital, and the manufacture of engines was begun on a large scale. The engine proved a marked success; and the firm of Boulton & Watt finally made a large fortune.

It is hard for us to realize, in these days of fine machine-tools, what difficulties had to be overcome by the young firm of Boulton & Watt. No one could bore a cylinder accurately in those days, which is evident from the following account that Watt has given us of one of his early tests:

"A cast-iron cylinder, over eighteen inches in diameter, an inch thick and weighing half a ton, not perfect, but without any gross error was procured, and the piston, to diminish friction and the consequent wear of the metal, was girt with a brass hoop two inches broad. When first tried the engine goes marvellously bad; but upon Joseph's endeavoring to mend it, it stood still, and that, too, though the piston was helped with all the appliances of a hat, papier-mâché, greases, black-lead powder, a bottle of oil to drain through the hat and lubricate the sides, and an iron weight above all to prevent the piston leaving the paper behind in its stroke. After some imperfection in the valves was remedied, the engine makes 500 strokes with about two hundredweight of coals."

Boulton, in 1776, wrote that: "Mr. Wilkinson has bored up several cylinders almost without error; that of fifty inches diameter, which we have put up at Tipton, does not err the thickness of an old shilling in any part." This would be considered inexcusably coarse work in these days, when errors of more than one ten-thousandth of an inch are not tolerated in the parts of some fine automobiles. The Mr. Wilkinson, of whom Boulton wrote so approvingly, was John Wilkinson, famous in the history of machine-tools. Wilkinson's was probably the first metal-working tool capable of doing heavy work with anything like acceptable accuracy.

The Newcomen engine was now doomed. Watt kept on making improvements. He found that it was wasteful to leave the steam-valve open while the piston was pushed from one end of the cylinder to the other. The pressure of the steam, as it came from the boiler, was more than enough to push the piston. He discovered that the valve could be closed soon after the piston started, and that the steam in the cylinder expanded and continued to drive the piston on. Hence he invented what has ever since been called the "cut-off," which means that when the piston has completed only about one-

fourth of its stroke the steam is automatically cut off from the boiler and permitted to expand so as to drive the piston for the remaining three-quarters of the stroke. Of course, the steam cools in thus expanding, but it is doing useful work as it cools. Hence the cut-off makes it possible to convert a large amount of heat into work; heat which would otherwise be wasted if it were carried into the condenser or the open air.

Later Improvements by Watt

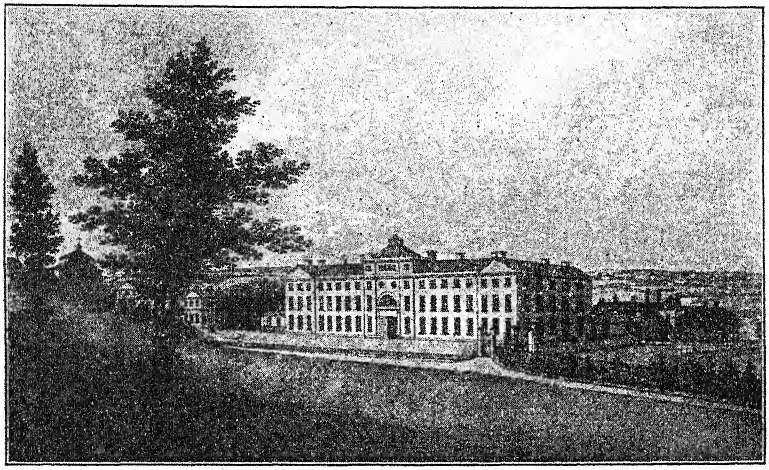
After a time Watt brought out a double-acting cylinder into which steam was admitted and allowed to expand alternately on opposite sides of the piston, as in all modern condensing engines.

The firm found it hard at first to convince a mine-owner just how much work a Watt engine could do. Many of the mine-owners used horses. Indeed, horses had done most of the pulling and lifting of the world up to Watt's time. So that Boulton or Watt had to interpret their claims in terms of horse-power. "This engine will do the work of forty horses," they would say. In order to live up to any such claim Watt first had to find out how much work a horse really could perform. He made some crude measurements which led him to conclude that in one minute a horse could lift 33,000 pounds through a distance of one foot. A horse-power, then, is 33,000 foot-pounds per minute, as engineers say. This measure of engine performance has been used ever since, although engineers are not satisfied with its accuracy.

Boulton was a good salesman. He sold engines on the strength of the fuel they would save. Mine-owners wanted to keep their fuel bills low. Newcomen's best engines consumed thirty-five pounds of coal in one hour for each horse-power. By studying heat and how to make the most of it, by inventing the separate condenser, and by making other improvements, Watt reduced this coal expenditure to eight pounds. In our best engines of to-day the coal consumed amounts to little more than a pound an hour for a horse-power hour. Even this is considered wasteful, because not more than thirteen per cent. of the energy in the coal is utilized.

The Invention of the Compound Engine

As the steam expands and cools in a cylinder the cylinder also cools. It ought to be hot, otherwise the next measure of steam will waste some of its heat in warming the cylinder again. Here we have exactly the same situation that Watt found in the Newcomen engine. If Watt could keep the cylin-



Courtesy W. and T. Avery, Ltd., London.

WHERE WATT'S ENGINES WERE MADE.

In January, 1796, the Soho Foundry, still in existence, was dedicated with considerable ceremony and a "rearing feast" given to the engine-smiths and other workmen. On this occasion Matthew Boulton made the following speech:

"I come now as the Father of Soho to consecrate this place as one of its branches; I also come to give it a name and a benediction.

"I will therefore proceed to purify the walls of it by the sprinkling of wine, and in the name of Vulcan and all the Gods and Goddesses of Fire and Water, I pronounce the name of it Soho Foundry. May that name endure forever and ever, and let all the people say Amen, Amen."

der of a Newcomen engine warm by leading the steam into a separate condenser, the same principle should apply to his own engine. In other words, allow the steam to enter one cylinder without cutting it off, and, after it has pushed the piston as far as possible, let it pass into a second, larger cylinder, there to cut it off and let it expand and push a second piston. This probably occurred to Watt; but he was prejudiced against high-pressure steam, and the idea could be carried out only if the pressure were high. So it was that Jonathan Hornblower, in

1781, saw that if two cylinders could be used in this way, he could save, by means of the cut-off, even more heat than Watt had done. He built engines on that principle which were very successful. Hornblower apparently came of a steam-engine family. One of his ancestors, Joseph Hornblower, is referred to in old books as Newcomen's "operator," and he was employed by Newcomen to superintend the erection of engines. Jonathan Hornblower threatened to become so formidable a rival that Boulton sued him for patent infringement and won the case. Boulton & Watt also drove other rivals out of business, and collected large sums in royalties and damages.

After Watt's patents expired Hornblower's excellent idea was called to life again, in 1804, by Arthur Woolf, another Englishman. If a second cylinder can make steam expand more, why not a third and fourth? This was first tried by Doctor A. C. Kirk, in 1874, who found that it was indeed possible to reduce the coal bill and get more work out of the heat in steam by thus adding more cylinders. There is a limit to the number of cylinders, however, and the limit seems to be four. By the time it has left the fourth cylinder the steam has given up so much of its heat that there is little left for a fifth. Even if there were a fifth the cost of constructing and operating the extra parts is greater than any saving in coal that can be effected.

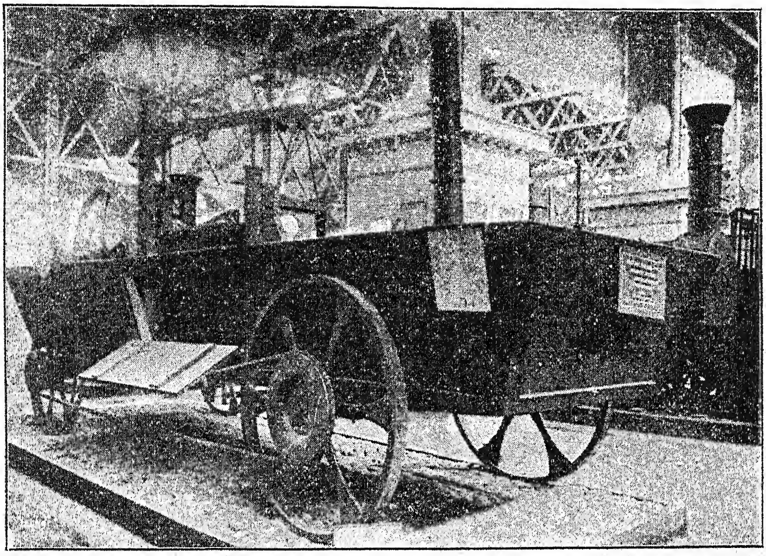
To use one cylinder after another in this way the steam must leave the boiler at high pressure. At first, 100 pounds to the square inch was regarded as very high pressure; now it is not uncommon to carry anywhere from 150 to 250 pounds. With pressure in excess of 250 pounds to the square inch difficulty is encountered in packing and lubricating the first cylinder.

Oliver Evans Invents the First High-Pressure Engine and Puts It to Work

Like Savery and Newcomen, Watt thought at first only of pumping water. To be sure, after he made steam instead of air do the work of moving a piston, he had produced an engine which could turn a shaft and therefore drive factory machines and railway-carriages and vessels.

It was an American who realized perhaps more keenly than

Watt how tremendously helpful the steam-engine could be in doing most of the world's hard, wearying work. This American was Oliver Evans, born in Newport, Delaware, in 1755. Evans was a farmer boy who, like many a great American inventor, had to educate himself. What he knew of history,



THE "AMPHIBIOUS DIGGER" OF OLIVER EVANS—THE FIRST AUTOMOBILE.

Philadelphia ordered a steam-dredge from Oliver Evans in 1804. His shop was a mile and a half away from the Schuylkill River. He mounted one of his engines within the dredge-scow and ran the scow on rollers by steam to the river. This was the first steam-wagon or automobile. When he reached the river Evans substituted a paddle for the rollers and steamed away to Philadelphia. Hence the invention was also one of the first steamboats. Evans named this craft *Oruktor Amphibolos*, or "Amphibious Digger." This is a picture of the Baltimore & Ohio Railway Company's reconstruction of the Amphibious Digger.

politics, and mechanics he learned out of books at night by the light of burning shavings. His brothers were millers, and, because of his mechanical ability, they took him into partnership with them.

The United States of Evans's time was a land of infinite possibilities. It had a territory so immense that even men like Franklin, Washington, and Hamilton did not know exactly where it ended west of the Appalachian Mountains. There were forests to be hewed down; coal and iron to be mined; untold, even unsuspected, riches were in the earth. What America

needed was men to develop these resources, and there were fewer men in the original thirteen States than there are now in Chicago and New York. Evans could not have known how rich the new republic was, but he did know that there were not enough men to till the soil or mine the earth. His inventive mind naturally turned toward machines that would do the work of men. Even at twenty-two we find him inventing a machine for making the teeth used in carding cotton and wool: a purely labor-saving device. In his brothers' flour-mill he was constantly struck with the need of machinery that would grind flour faster than was possible with the crude water-wheel of the day, and carry it away automatically to be sacked. The United States granted him one of the three patents it issued in the first year of its existence; a patent on flour-mill machinery.

One day a book which described Newcomen's engine fell into his hands. He knew nothing about engines, but his inventive mind saw at once that while the pressure of the atmosphere worked the piston Newcomen did nothing with the steam beyond producing a vacuum by condensation. Why had not Newcomen used the elastic force of steam? He asked himself the question over and over again. Constructed so as to employ and utilize its steam, an engine could be used for other purposes than pumping water; it would be a real power-generator, something that would drive other machines and thus do the work of hundreds of hands. Evans thereupon resolved to invent a steam-engine, a real steam-engine and not a mere pump. His drawings of a high-pressure engine, which could actually be used to drive other machines, and which was the first steam-engine of the kind ever invented, he sent to England in 1787. Richard Trevithick, an Englishman, the first man to build a locomotive, came out soon afterward with a high-pressure steam-engine, but there is good reason to believe that he saw these drawings of Evans's. Watt was prejudiced against high pressures; and yet, unless they were used, the steam-engine could not be employed to the utmost advantage in factories. Hence, to Evans belongs the credit of having produced an engine, independently of Watt, which made it possible to drive factory machinery.

Evans built a high-pressure engine and showed how ma-

chines could do the work of the men the United States lacked. In 1801 he gave public exhibitions to prove that his engine could drive machines that ground plaster and sawed marble. Evans found it hard to convince business men that new ideas are worth carrying out. His efforts to introduce his engine almost ruined him. Undaunted, he kept on. He applied his engine

OLIVER EVANS.
Inventor of the high-pressure steam-engine.

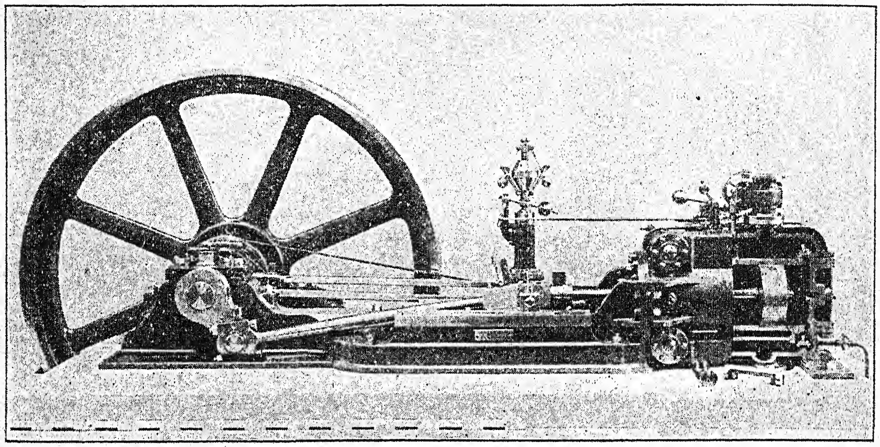
SIR CHARLES A. PARSONS.
Inventor of the Parsons steam-turbine

in his flour-mill. At the same time he invented flour-mill machinery which, in principle, is the same as that we find to-day in the great mills of the Middle West.

In 1803 he became a regular builder of engines. Philadelphia ordered a steam-dredge from him with which to clean the city docks. His shop was a mile and a half away from the Schuylkill River. Resourceful, practical man that he was, he mounted one of his engines within the scow and ran the scow on rollers by steam to the river. That was the first steam-wagon. But Evans did more than this. When he had reached the river, he substituted a stern paddle for the rollers and steamed away on the water to Philadelphia. The scow, christened by Evans, *Oruktor Amphibolos* ("Amphibious Digger") was, therefore, not only the first automobile, but also one of the first steamboats. Indeed, the Mississippi stern-wheeler is noth-

ing but a steam-driven scow, with cabins and cargo spaces, but larger than the one made by Oliver Evans.

Evans intended to write a long, learned book about his steam-engine, profusely illustrated with explanatory drawings, and to be called *The Young Engineer's Guide*. But his disappointments, and the straits into which he had been plunged by

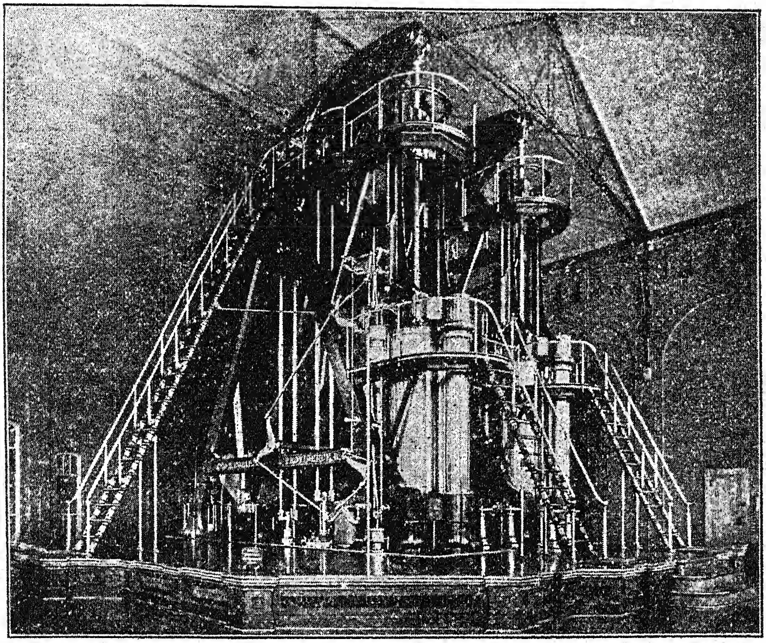


CORLISS ENGINE.

The original Corliss valve-gear was invented in 1849 by G. H. Corliss. The leading features of the invention are: The employment of separate steam and exhaust valves at each end of the cylinder, so that any alteration of the point at which steam is cut off can be made without interfering with the action of the exhaust-valve; and separate adjustment for each of the cylindrical valves. The two exhaust-valves which are at the bottom of the cylinder are rocked by a single eccentric, while the two steam-valves at the top are rocked by another eccentric. The steam eccentric swings an arm provided with a cylindrical end upon which are two hardened steel plates; as the arm swings these plates engage with similar plates attached to flat levers that proceed from cranks on the spindles of the two steam-valves. As the arm reciprocates, the steam-valves are alternately opened, but, at certain points, determined by the speed of the governor, the lever of the steam-valve then opening slips off the corresponding driving-plate; the valve then left free is rapidly turned into a closed position by a coiled spring.

his first attempt to build and sell engines, forced him to compromise on the book, which was considerably reduced and grimly renamed *The Abortion of the Young Engineer's Guide*. He wrote other books and pamphlets, in which he described his flour-mill machinery and foretold with remarkable accuracy what might be expected of power-machines. In an "Address to the People of the United States," in which he poured forth all his troubles as an inventor, he says:

"The time will come when people will travel in stages moved by steam-engines from one city to another almost as fast as birds fly—fifteen to twenty miles an hour. Passing through the air with such velocity—changing the scene in such rapid succession—will be the most exhilarating, delightful exercise. A



Courtesy Pullman Company.

HUGE ENGINE BUILT BY CORLISS FOR THE PHILADELPHIA EXPOSITION OF 1876.

It was afterward bought by the Pullman Company and did service in its plant for over a generation.

carriage will set out from Washington in the morning, and passengers will breakfast at Baltimore, dine at Philadelphia and sup at New York the same day."

He was not referring to ordinary steam-driven road coaches, such as Sir Goldsworthy Gurney introduced in England years later, but to *railway* carriages; for he goes on to describe rails on which the carriages are to run. "And the passengers will sleep in these stages as comfortably as they now do in steam stage-boats."

The worries which beset him and which prompted him to pour out his woes in this amazing "Address," led him to destroy the drawings and records of no fewer than eighty inventions. The final blow came when a fire destroyed his factory in 1819. He died a few months later, a bitter, discouraged man, yet a great pioneer inventor in the annals of American industry.

Corliss and His Drop Cut-Off

Evans was the first of a line of American inventors who helped to make the steam-engine what it is to-day, and certainly the first in America to apply it industrially. We have to wait until 1849 before another man appears with improvements that heightened the usefulness of the steam-engine. In that year an American, George H. Corliss, received a United States patent for an engine which has not been greatly bettered to this day. Engineers rank Corliss with Watt when they trace the history of the steam-engine.

Corliss, a born inventor, had to teach himself the rudiments of mechanics, but, like his predecessors, Watt and Evans, his mechanical ideas were inexhaustible. How fertile was his mind is revealed by the fact that even when scarcely more than a boy he performed a feat that civil engineers had declared impossible. A freshet had swept away the bridge near the village of Greenwich, New York, where he lived. Unless this bridge were rebuilt the village would practically have been cut off from supplies. There was no time to wait for the water to subside. The bridge must be reconstructed at once. "Impossible," said the engineers. Corliss set to work and rebuilt the bridge in ten days at a cost of fifty dollars.

While he was still a country storekeeper, Corliss invented a sewing-machine; and this before Howe. Dreaming of the wealth that would be his if he could manufacture and sell this machine, Corliss set out for Providence to raise the needed money. There he arranged with the steam-engine building firm of Fairbanks & Bancroft to perfect the machine. Corliss had an attractive personality and his ingenuity pleased the firm. Fairbanks & Bancroft had no particular faith in his invention, but they had a great deal of faith in Corliss. They offered him a position on condition that he would give up the

foolish machine. Poor as he was he accepted the offer. One year later he became a partner.

The sewing-machine was abandoned, but Corliss thought of other machines. He made a profound study of the engines of his day. By this time the steam-engine had taken its place in thousands of factories in Europe and in hundreds in the United States. These factory engines had to adapt themselves to the machines they drove; in other words, sometimes all the machines were running, so that the engines were taxed to the utmost to deliver power, and sometimes only a few machines were in operation. It was clearly impossible, when men and women in the factory called "more power," or "my machine is shut off," for the engineer to regulate his engine in accordance with their demands. Hence, Watt invented the "ball-governor," a sleeve which can slide up and down a rod or pipe, and which is connected with two whirling balls. When some of the factory machines were shut off, the engine would naturally speed up, whereupon the balls would whirl around faster and would be flung out farther. This raised the sleeve and cut off some of the steam supplied to the engine. As more and more machines were thrown into operation, the balls would whirl more slowly and fall slightly; consequently the sleeve would drop and permit more steam to reach the engine. Thus Watt made it possible for an engine automatically to speed up or slow down in accordance with the factory demands.

Ingenious as the ball-governor was, it had its faults. The engine had to speed up or slow down before the big steam-valve could be moved by the ball-governor and its sleeve. In a textile mill the spindles of a spinning-machine run very fast. The slightest variation in speed of the engine that drives the machine is multiplied many times at the spindle. If the spindle runs too fast the work produced is spoiled; if it runs too slow the output is low. It was difficult to make a Watt ball-governor that would be responsive enough to meet this situation. Corliss invented a much more sensitive governor, a "valve gear," one that seemed so complicated to engineers of the day that they poked fun at it, and at first refused to take Corliss engines seriously:

"Levers, links, and motions various
Endless jimcracks all precarious."

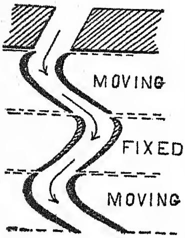
Thus ran a couplet composed to express the current opinion of the mechanism that was offered as a substitute of the Watt ball-governor.

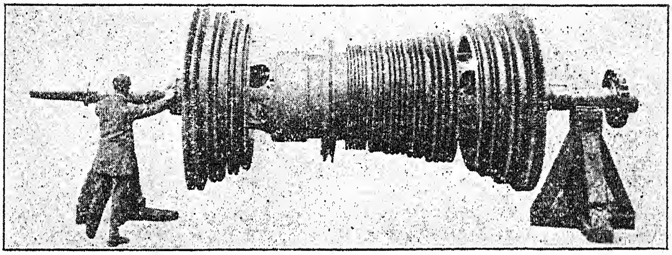
What was this new device that seemed so strange? The Watt engine had what is called a "D" slide valve, and it was so named because it was shaped like the letter "D." The slide valve opens and shuts just like a sliding door, to admit and shut off the steam. The "D" slide valve for a large engine is massive, and steam pressure keeps it tightly closed. This produces friction and wastes power. Corliss invented a valve that worked like a revolving door: a rotary valve. He used these revolving-door valves at each end of the cylinder, one to admit the steam, and one to control the exhaust. A slight motion of one of these valves was sufficient to open or close the steam port or doorway almost without friction. To open and close his rotary valve, or revolving steam-door, automatically, Corliss invented a governor which was apparently composed of "endless jimcracks all precarious." By a system of parts, certainly more complicated than the simple ball-governor and sleeve of Watt, a weight was made to drop and suddenly cut off the steam as it entered the cylinder and not, as in the Watt engine, some moments later. For that reason this invention by Corliss is called the "drop cut-off." If only a few machines in the factory happened to be running, the drop cut-off would shut off the steam after the piston had moved only a few inches. This was not only a saving of steam, but also of fuel. The cut-off acted like an attendant who holds a revolving door when he wants to hold back a crowd and helps to turn it when he wants to hurry it up.

Finding it difficult to convince business men that his engine was any better than Watt's, Corliss had to take risks in selling it. He knew his engine would save coal, and therefore he adopted a plan similar to that which Boulton & Watt had found successful: the plan of installing an engine free of charge and of receiving in payment part of the money saved in coal. He sold one of his first engines with the understanding that he was to be paid all the money it saved in five years. At the end of five years he had pocketed $19,734.22—several times what the engine was really worth. This shrewd business policy made Cor-

liss rich and gave him the necessary money to fight infringers. One of his patent-infringement suits lasted fifteen years, and cost him $100,000.

When the Philadelphia Exposition of 1876 was planned, Corliss suggested that one large double engine was enough to furnish all the power required to drive the machines in the Machinery Hall. But no one could build the engine. "Im-





Courtesy Westinghouse Electric and Mfg. Co.

(Left) COURSE OF STEAM-JET BETWEEN FIXED AND MOVING BLADES—PARSONS TYPE TURBINE-ENGINE.

(Right) THE "ROTOR" OR MOVING BLADES OF A WESTINGHOUSE-PARSONS STEAM-TURBINE.

possible," said the engineers again. Then Corliss decided that he would build the engine himself. When he set it up it was the mechanical marvel of the exposition. It was afterward bought by the Pullman Company and ran in its shops until 1910.

The Invention of the Steam-Turbine

In the steam-engine, as Watt handed it down to us, the piston moves back and forth, or up and down, in the cylinder, just as it does in an automobile engine. This is called a "reciprocating" motion, and engines in which pistons thus move are therefore known as "reciprocating engines." This back and forth, or reciprocating motion, cannot be used to drive a wheel or a shaft directly. It must be changed to a turning or rotary motion. For this purpose cranks are used. They are found in the reciprocating engines of automobiles, and by their means a shaft is turned and the wheels of the automobile are made to revolve.

Why was it not possible to make the steam turn a wheel directly, just as the wind turns a windmill or a stream a water-wheel? Some of the earliest engines of which we have any record were built on this principle. There was the engine of Hero, a mathematician, who lived in Alexandria, Egypt, about 130 B. C., an engine which was little more than a toy, but in which there was a wheel that was whirled around by steam escaping from bent tubes. In 1629, Giovanni Branca, of the great Italian University of Padua, also succeeded in moving wheels by blowing steam against their paddles. Watt, too, thought so much of this principle that he tried to apply it, but he soon abandoned it because of the many mechanical difficulties he encountered. For generations inventors had tried to do away with the to-and-fro motion of the piston.

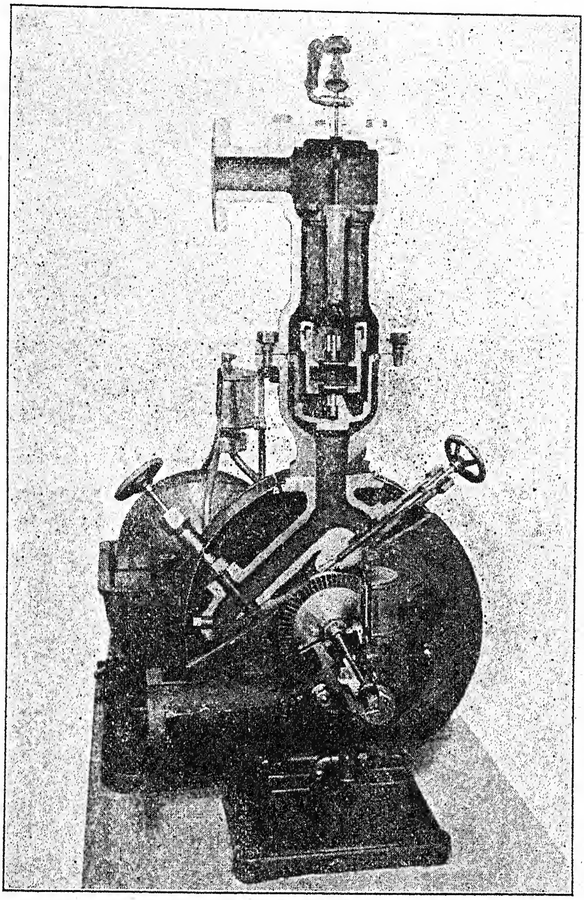
Literally, hundreds of patents had been granted to inventors in England and the United States for rotary engines, not one of them of any practical value, when, toward the end of the nineteenth century, the dynamo, or electric generator, was introduced. The generator is a high-speed machine, and by comparison the reciprocating engine is slow. But it was difficult to adapt the slow engine to the fast generator, and unless that was done neither could be used economically.

It was not easy to design and build an engine according to the ideas of Watt and Corliss which would turn the generator continuously at high speed; the generator had to be made large to suit the speed of the engine, and power-wasting belting or gearing had to be used in order that the generator might turn at two and three times the speed of the engine. A faster engine was needed. Rotary engines were fast; accordingly inventors tried once more to solve the old, seemingly hopeless problem of building them.

The De Laval Steam-Turbine

In 1889, Doctor Gustaf De Laval, a Swedish engineer, brought out the first practical rotary engine: a turbine. He took a disk or solid wheel and cut vanes in its rim. Against these vanes, nozzles, properly placed, shot jets of steam. After having struck the vanes the steam was allowed to escape. De Laval's disk was something like a pinwheel. Because it cost

too much in steam, and therefore in fuel, to blow steam against vanes in the open air, De Laval enclosed his disk in a tight cylinder, rather flat. Everything depended on the shape of the



DE LAVAL TURBINE.

This remarkable machine owed its success to the discovery by Doctor Gustaf De Laval in 1889 of the fact that the velocity of the particles of an escaping jet of steam is increased by discharging through an expanding orifice, the conversion of the energy of the steam into momentum being so complete that when applied to a form of Pelton wheel or impulse turbine a high efficiency is obtained.

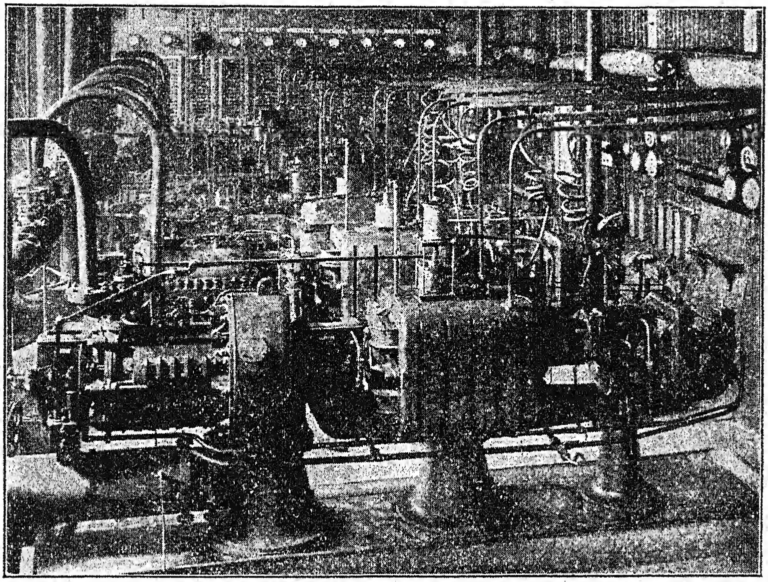
nozzles and the vanes. The nozzles had to shoot the steam at the highest possible speed, and the vanes had to be so shaped that they would let the steam do its work most effectively and not waste its force by recoiling upon itself.

About the time that De Laval was conducting his experimenting, an English engineer, Charles A. Parsons, since knighted, invented a turbine entirely different in character. Unlike most inventors Parsons was a rich nobleman's son. His father was the Earl of Rosse, famous in his time because he built one of the largest telescopes in the history of astronomy, an instrument that was one of the wonders of the world. Parsons spent his boyhood in a moated castle under the influence of a father noted for his public spirit and his scientific attainments. To build the big telescope a foundry and machine-shops had been fitted up in the castle grounds. Here young Parsons spent much of his time. Sir Robert Ball, who was his private tutor—the Earl of Rosse had a deep-rooted prejudice against all schools—said that Parsons was forever in the shops making machines or tinkering. Later, the young man was sent to the University of Cambridge where he graduated with high honors. Parsons then apprenticed himself to the firm of Armstrong & Whitworth, famous in English naval history for its guns and battleships. Here, under the eye of Whitworth, one of the most ingenious mechanics and engineers of our time, Parsons learned the art of successfully attacking a mechanical problem.

After he had served his apprenticeship and had become junior partner in an engineering firm, Parsons began to think seriously of a steam-turbine. In 1884, he took out his first patent; so that he began work even before De Laval.

Parsons used more than a single wheel or disk. He strung a large number of disks in a row on a shaft and enclosed them all in a cylinder or drum. It must not be inferred that he blew an individual jet of steam against each set of blades. Instead, he blew a single current of steam from one end of the cylinder to the other, and subdivided it into little jets, each playing upon successive blades. Therein lay the novel feature of his great invention. He subdivided the steam current by studding the inner surface of the long, enclosing casing with rings of blades, fitting or dovetailing between the shaft blades. The casing blades were fixed; the shaft blades turned. The fixed blades guided the tiny streams of steam to the moving shaft blades at just the right angle, so that the steam would not get in its own way. (See diagram, page 493). The blades of both casing

and shaft were curved so that although the steam entered the casing parallel with the shaft it was shot against the blades just as you would blow air against the vanes of a pinwheel. The steam literally writhed through the turbine, worming its way from fixed blade to moving blade, until its energy was



Courtesy C. A. Parsons & Company.

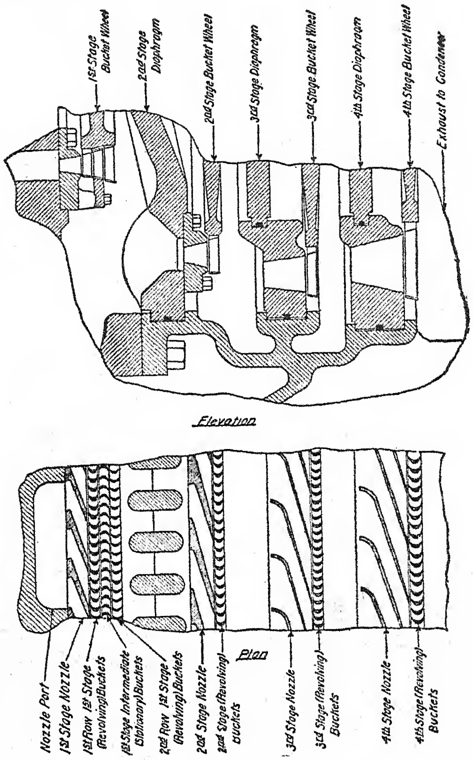
THE FIRST POWER-HOUSE EQUIPPED WITH PARSONS TURBINE.

Turbo-generators in the plant of the Newcastle and District Electric Lighting Co., Limited.

spent in a parting kick administered to the last ring of shaft or moving blades.

The turbine invented by Parsons proved successful almost from the beginning. If the old reciprocating engine was too slow this new engine was too fast. It ran faster than any dynamo or generator, indeed ten and even fifteen times as fast. Instead of being a fault this proved a virtue. It became possible to build smaller, faster dynamos that would deliver just as much current as the old, bigger, slower dynamos. Soon Parsons's turbines were introduced not only in power-houses, but also on ships. Some of the fast transatlantic liners, among them the *Mauretania*, are driven by Parsons's turbines, and some of the

great fighting ships that won the day for England at Jutland were turbine-propelled.



PLAN AND ELEVATION SHOWING STEAM PASSAGE IN A FOUR-STAGE CURTIS STEAM-TURBINE.

Curtis's turbine consists of a set of disks, each turning in a separate compartment. After the steam has acted on the first disk it is shot into a compartment where it accumulates and produces back pressure. This has the effect of slowing up the shaft. The steam next passes to another set of nozzles and is discharged against a second disk at a lower pressure. Here, again, it accumulates and discharges against a third disk, and so passes through perhaps a dozen stages.

Curtis Combines the Ideas of De Laval and Parsons

Difficulties are encountered in the manufacture of both De Laval's and Parsons's turbines. It is difficult to balance parts properly that turn at 15,000 revolutions a minute, and thousands of little blades have to be fitted very carefully.

Charles E. Curtis was an electrical manufacturer in Brooklyn, New York, when he first thought of his turbine. He helped

to invent the electric fan now used in every office and home. With the money that he made he pushed his conception of a turbine to success. In the De Laval turbine the steam blows against one set of blades on a disk and expands in a single jump; in the Parsons turbine the steam blows against one set of blades, then against set after set, each time expanding a little, until finally it leaves the machine expanded to the utmost and with scarcely any energy left. Curtis combined the ideas of De Laval and Parsons. De Laval's steam jets shot against the blades at a speed of 4,000 feet a second—nearly twice as fast as a rifle-bullet. The steam was travelling so much faster than the blades could turn that energy was lost. On the other hand, Parsons had trouble with his blades. There were literally millions of them in the turbines of a great power-house or steamer, all carefully set by hand. Moreover, the fixed blades and the moving blades had to dovetail so closely that not more than three-hundredths of an inch was left between some of them; so that if the steam was turned on suddenly some blades would be stripped off as the shaft turned, because they had expanded unevenly and touched dovetailing blades. By combining the principles of De Laval and Parsons, Curtis invented a machine which had the good features of both without their faults. His turbine consists of a set of De Laval disks, each turning in its separate compartment. The steam acts on the first disk, just as it does in the De Laval turbine, but, instead of being discharged into the open air or into a condenser, it is shot into a compartment where it accumulates and produces back pressure. This has the effect of slowing up the steam jets so that the shaft does not need to run so fast as in the De Laval turbine. The steam next enters another set of nozzles and is discharged against a second disk at a lower pressure. Here, again, it accumulates and afterward discharges against a third disk, and so through perhaps a dozen stages. To reduce the speed of a Parsons turbine the engineer reduces the steam pressure, which results in waste. To reduce the speed of a Curtis turbine the engineer simply cuts off steam from one or more nozzles, so that the machine can run economically at low speed as well as at high.

The steam-turbine of Curtis is a very great invention, the

last word in steam-engines. It has been so successful that even in England it is competing with Sir Charles Parsons's invention. It was not developed overnight. Curtis spent $60,000 on it, and then sold his patent rights to the General Electric Company, in the research laboratories of which over $3,000,000 were paid out in bringing his turbine to its present stage of perfection. Three million dollars is more money than there was in all England in the time of Richard the Lion Heart. That huge sum was an investment in an engineering idea, an investment that has paid rich dividends when it is considered that Curtis's turbines on land generate 15,000,000 horse-power, on sea 20,000,000 horse-power, and that the British navy uses Curtis's turbines having a combined horse-power of 5,000,000.

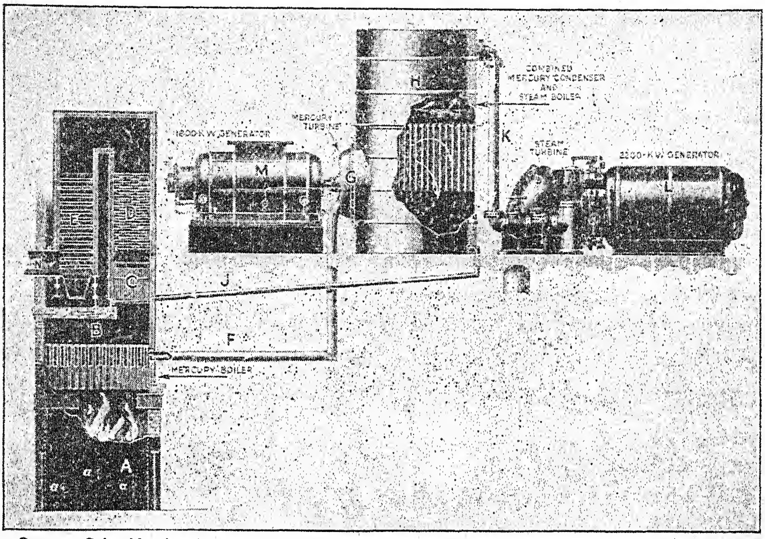
The Curtis turbine was brought to commercial perfection by Mr. W. L. R. Emmett of the General Electric Company. To his efforts is it due that our battleships are now electrically driven; that is, the steam-turbines drive not the propeller directly but electric generators and motors with which the propeller-shafts are connected.

With the development of the Curtis turbine it seemed as if the story of the steam-engine had been brought to a close. And yet Emmett saw further than the Curtis steam-turbine. As an engineer he knew that the steam-engine is a heat-engine, and that its chief purpose is to convert the energy liberated by burning fuel into useful work. The more heat that one can obtain, the more work results. From Watt to Curtis all efforts had been directed toward utilizing more and more heat. Temperatures had been raised to the utmost. Water cannot exist in a boiler above the critical temperature of 706 degrees Fahrenheit, and even then the pressure will be over 3,000 pounds to the square inch, which is quite outside the range of ordinary practice.

Water has its limitations. Can any other liquid be used? Emmett determined to experiment with quicksilver or mercury. Water boils at 212 degrees Fahrenheit; mercury at 677 degrees Fahrenheit. Therefore it can store up more heat and do more work.

Emmett began to experiment with mercury about 1912. With the financial resources of a great manufacturing organiza-

tion behind him, he was able to spend hundreds of thousands of dollars in experiments. Finally, in 1923, he had reached a point where he was able to drive electric generators of the Hartford Electric Light and Power Company with mercury vapor.



Courtesy Scientific American.

THE EMMETT MERCURY-STEAM POWER-PLANT.

Water boils at 212 degrees Fahrenheit; mercury at 677 degrees Fahrenheit. Hence mercury can store up more heat (energy) and do more work. W. L. R. Emmett after twelve years of experimenting successfully applied the idea in this mercury-steam plant of the Hartford Electric Light and Power Company. Mercury is vaporized in a special boiler, B, with ordinary fuel—coal or oil. The mercury vapor, at a temperature of 677 degrees and pressure of 35 pounds, is supplied to a single-stage turbine, G, which drives an electric generator, M. After leaving the turbine it still has a temperature of 455 degrees—hot enough to boil water. It is passed through a condenser, H, where it boils water and raises steam, which is fed through a pipe, K, to a Curtis steam-turbine coupled with an electric generator. Thus the vaporized mercury not only drives a turbine but raises steam which drives another turbine.

Even this experimental installation cost $500,000. It was the fifteenth that Emmett had designed up to that time.

Let us examine this 6,000 horse-power Hartford installation with the aid of the illustration on this page. Mercury is boiled in a special boiler with ordinary fuel—coal or oil. Vapor is given off at 677 degrees Fahrenheit at thirty-five pounds pressure. It is supplied to a single-stage turbine which drives an electric generator. After having spun the turbine it still has a tem-

perature of 455 degrees. If the vapor were to be discharged or collected then and there, mercury would show no improvement over water. This hot, condensed liquid mercury can do much more work. Emmett passes it through a condenser and makes it serve exactly the same purpose that glowing coals serve under a boiler. He heats water with it—raises steam. So this condenser is really a kind of steam-boiler. The mercury passes through a series of tubes; water surrounds the tubes; hence the intensely hot liquid mercury boils the water and raises steam which is fed to a Curtis steam-turbine coupled to another electric generator.

Mercury costs about a dollar a pound. Moreover, its vapor is poisonous. For these two reasons it must not be allowed to escape. From the condenser-boiler the liquid mercury flows to a heater right in the path of the hot fuel gases of the mercury-boiler. Thus it is preheated and finally passed back to the main mercury-boiler. The cycle then begins all over again.

Thus the fuel gases are used to the utmost before they escape up the smoke-stack; and the mercury is not allowed to escape at all. The vaporized mercury is made to do double work—to drive a mercury-vapor turbine and to generate steam for a steam-turbine. Because mercury condenses at a temperature more than twice that of boiling water and stores up more heat from a fire than water the efficiency of the Emmett power system is unprecedented. Hartford has a population of 175,000. It costs $1,500,000 annually for coal to supply this population with electric light and power. With the mercury process the coal bill is cut in half; for the Hartford plant, with steam at 200 pounds pressure, can produce with mercury vapor at thirty-five pounds pressure, fifty-two per cent. more electric energy for each pound of fuel consumed. "And if," Emmett adds, "in such a plant the steam-boiler were re-equipped with furnaces and mercury apparatus arranged to burn eighteen per cent. more fuel, the station capacity, with the same steam-turbines and auxiliaries, would be increased about eighty per cent."

With Emmett, the American inventor, we bring the story of the steam-engine, probably the greatest of all inventions, to a close. Watt, Evans, Corliss, Parsons, Curtis—their work centralized industry in single huge factories and towns, gave

us the fabric of modern civilization, and raised the standard of living to a degree undreamed of only a century and a half ago. The great revolutions of England, America, and France gave men political freedom; but Watt and his successors gave them the machine that meant freedom of a different kind, a freedom that has expressed itself in the slave-machines that now do so much of the world's work. Millions of horse-power, thousands of millions of tons of coal, billions of barrels of oil are the measure of our country's wealth; a measure that meant little or nothing before the invention of the steam-engine. Now our engines generate every hour in the day and night 125,000,000 horse-power, of which over eighty-two per cent. must be credited to steam.

Perhaps Boulton had an inkling of what was to come when he aptly crystallized the significance of the steam-engine in a conversation with George the Third:

"In what business are you engaged?" asked the king.

"I am engaged, your Majesty," said Boulton, "in the production of a commodity which is the desire of kings."

"And what is that? What is that?"

"*Power*, your Majesty," replied Boulton.

And he was right. The steam-engine is king of the world.

CHAPTER II

THE RISE OF ELECTRICITY

The First Sparks

THE history of the rise of electricity is every whit as fascinating as the story of Aladdin's lamp. Aladdin rubbed his lamp and all things were possible of accomplishment. To-day we press a button to achieve similar wonders. From the days of Thales, 600 years before Christ, to the time of Benjamin Franklin, the world's philosophers and inventors were busy briskly rubbing amber, sulphur balls, and pieces of glass, and getting wonderful electric sparks. Their simple experiments one may repeat now on a dry, cold day by chafing a hard-rubber penholder on the sleeve of one's coat, or by merely shuffling one's feet on the carpet.

Most of us have lit a gas-jet with finger-tip sparks. That spark has greater magic than Aladdin's lamp. The lamp and its owner were unreal. The electric spark is omnipotent, its power everlasting. Inventors, experimenting with electricity, soon noted that this "frictional" electricity could be "conducted" from one place to another; and Stephen Gray, in England, about 200 years ago, began sending the current hundreds of feet over circuits of packthread held up by silken loops, or "insulators." Living at a famous London charity school, Gray, as a poor pensioner, was glad to get the inexpensive help of the boys for his queer experiments. While the youngsters were doubtless scared, they must have found Gray's experiments more amusing than their school lessons, especially as there were such things to handle as a hot poker, a live chicken, a big map, and one of those new, fashionable articles, an "umbrella." The boys were hung up in the air, and electrified. They blew soap-bubbles to which the "charge" jumped from their toes or their noses. When they got tired of bobbing around in loops of hair, like trapeze performers, they were stood up on cakes of resin and charged and discharged, all

crackling and sparkling, until that gloomy playground of the grimy old Charterhouse School anticipated a dazzling comic scene at the Hippodrome in modern New York. The show was free to anybody who would poke his head through the stone gateway.

C. F. Dufay, in France, repeated these experiments and sent electricity over a wet string 1,256 feet long, and was merciful enough to use only one child. He found there were two kinds of electricity, which he called "vitreous" and "resinous," names that stuck long after scientists began to use the terms "negative" and "positive." He saw that like electricities repelled each other, while unlike electricities attracted. He also used solid insulators of Spanish wax, in place of silken loops, to hold up his circuit of thread. Dufay noted that bodies might be electrified either by direct touch or by "induction" through the air, and he conceived the clever idea of a whirl or "field of force" around his glass tubes, on which there was a charge of static electricity, due to the same old rubbing.

Cheered by friendly advices from the great Frenchman, who founded the famous Botanic Gardens in Paris, poverty-stricken Gray in his humble Grey Friars' shelter, went at it again, overworking his little collection of accessories, which now included tea-kettles, fishing-rods, a "pint pot," pewter plates, and a sirloin of beef—not forgetting the small boys, wincing as they felt the sparks through their woollen stockings. Above all, Stephen Gray hoped that a way might be found "to collect a greater quantity of electric fire." Like others, he was impressed by the crackles, the "brushes" of flame, glows, and "rays of light," and he set it down in memorable black and white, that the force he was demonstrating seemed, comparing small effects with great, "to be of the same nature with thunder and lightning."

Early Attempts at Harnessing Electricity

The boys, handy to philosophers, must have had an uncomfortable time while sparks of greater size, sting, and dazzle were being obtained and tested. Eventually the electricity obtained from the frictional machines was actually "stored." A Scottish monk, Gordon, teaching in Germany, soon after

Gray's death, in 1736, invented the first electric bell. It had two little gongs, between which hung a metal ball on a silken pendulum. The charged ball struck one gong, gave up its electricity in doing so, and, being repelled, struck the other gong; so on, over and over again. Gordon, perhaps more of a mechanic than a monk, then invented a tiny motor. It was a metal star pivoted at its centre with the ends of its rays slightly bent aside all in the same direction. The reaction of the electric discharge kicked the star around on its pivot. This same monk, Alexander Gordon, was also the inventor of electrocution; for he killed many chaffinches with a smart discharge from his frictional machine, by which same principle Thomas A. Edison, about a century later, got rid of the cockroaches when they came uninvited to eat his supper as he worked at the night operator's telegraph-key in Boston.

Following Gordon's discoveries, the stage had arrived where electricity became useful to man rather than serving him merely as a medium for philosophical diversion. Up to the middle of the eighteenth century, practically only one really useful invention, the compass, could be attributed to the discovery of magnetism.

A period of electrical invention had now dawned, and continuing his excellent experiments Gordon ignited spirits by contact with a jet of electrified water. Many an American fireman, fighting flames, has since then found that the stream thrown against a burning building could carry inversely at the same time a deadly current back to him from some adjacent bare wire.

Not to be outdone by Gordon, a clever apothecary in London, named Watson, set fire to hydrogen with the electric spark, just as gas is now ignited in automobiles. Watson also exploded gunpowder and fired a musket after this fashion, thus being the first inventor of a vast range of various methods for electrically detonating explosives, mines, torpedoes, and other industrial and warlike devices.

Bottling Electricity

Out of all these inventions, one stood out by reason of its greatness. It was called the "condenser." As often happens

when there is a wave of invention along a particular line, several men claimed the condenser to be the product of their individual genius. In the maze of electrical experiments of this period it is hard to decide whose claim was the most justifiable. Probably two or three hit upon the identical idea simultaneously.

In Leyden, Holland, Pieter Van Musschenbroek, in 1746, having noted that electrified bodies lose their charge, conceived the idea of bottling a quantity of it for preservation. To do this he decided to electrify some water in a jar. The experiment, though absolutely successful, almost resulted in disaster. While his assistant was disconnecting the communicating wire, Van Musschenbroek received a nasty shock in his arms and chest as all the stored static electricity ferociously leaped out at him. The astounded professor instantly indulged in language which had nothing to do with scientific research, and he wrote to his friend René Réaumur, the famous French physicist, that he was literally all broken up and would not chance another such shock for a kingdom. In 1745, Dean von Kleist had done just about the same thing with a medicine bottle, and perhaps, as we say to-day, the patent should have gone to him. Watson, however, put some neat touches on what ever since has been known as the "Leyden jar," by coating it inside and out with tin-foil. Then came some magnificent experiments to close this whole series of observations and investigations, extending over a period of two thousand years. In France, the Abbé Nollet took a company of the king's soldiers, joined their hands to form the circuit, then knocked them over like human ninepins with a shock not far inferior to that which the doughboys got in the late war when they ran into some "live" barbed-wire entanglements set up by the foe. In England a committee of the Royal Society sent an "electrical commotion" from the "charged phial" over "wire" circuits set upon "dry sticks"; circuits of a total length of four miles, inclusive of water in large ponds. Then came Benjamin Franklin.

Franklin Draws the Lightning from the Sky

It has been forcefully said that Franklin's proof of the identity of man-made frictional electricity with the electricity of the thunder-storm subdivided history much as the birth of

Christ subdivided the forms of worship. Franklin snatched the lightning from the sky with a bit of a kite and a silk handkerchief stretched on two light strips of cedar. In Philadelphia to-day, in a dingy old building, one may still see Franklin's glass-globe friction-machine, made in America, with the aid of which and other quaint appliances he pioneered in the detec-

Cou tesy of E. Gottschalk

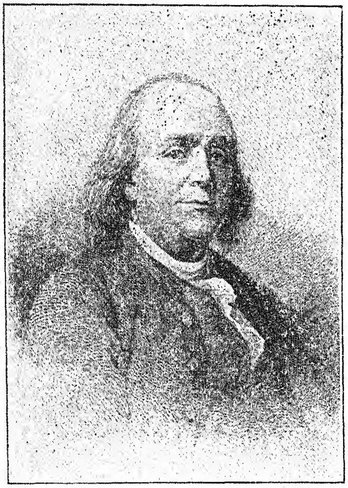
FRANKLIN'S KITE EXPERIMENT.

Franklin's kite experiment proved that lightning and laboratory electric sparks are the same in nature. Theoretically Franklin ought to have been killed. One of his imitators in Europe fell a victim to similar daring.

tion of many new electrical principles and phenomena. With his six-gallon Leyden jar he knocked out six men at one discharge. The only pity is that instead of giving all his time to the study of electricity, Franklin was able to devote to it barely nine years of his life. He was interested in so many things: printing, books, libraries, schools, and, above all, politics. Many million American citizens to-day are toasting their shins in front of Franklin stoves, reading Franklin journals, putting money into Franklin savings-banks, and using Franklin post-

office facilities. He dearly hated King George of England, and it is interesting to recall that his remote predecessor, Thales the Grecian, fell out of royal favor "by being too free in his opinions concerning monarchs."

Franklin, as early as 1750, imitated the effects of lightning before catching and taming it. Moreover, experimenting with



BENJAMIN FRANKLIN, THE FIRST AMERICAN ELECTRICIAN.

"THE GREATEST EXPERIMENTER WHO EVER LIVED."

Right—Michael Faraday, discoverer of electrical induction, the basis of the modern generator, motor, telegraph, telephone, and radio communication. Du Bois Reymond regarded him as "the greatest experimenter who ever lived."

ship compasses, "we have frequently given polarity to needles and reversed it at pleasure." In 1752, primitive Franklin lightning-rods were stuck up in France, and without fail they became electrified, though it was not shown that the aerial lightning had done it. To Franklin himself was fitly left the supreme proof. In June, 1752, he sent up his toy kite. A sharp-pointed wire stuck out and above from its upright cross-bar of wood. To the twine of the kite-string a silk bow was tied at the land end, and a key was knotted into the bow. Sheltered in a doorway to keep the silk bow dry, Franklin and his son, a youth of twenty-two, amid the sharp shower of rain, flagged the oncoming thunder-heads. Soon the loose filaments

of the twine stood out like porcupine quills, a finger could attract them, and before long the key sparked briskly when touched by Franklin's knuckle. The daring experiment was a success!

Electricity from the very skies was thereafter stored in Leyden jars as easily as if it had come from a friction-machine, and all the familiar effects were produced with unbelievable success. Franklin, to make conviction doubly sure, showed that the distant clouds were sometimes charged positively, sometimes negatively. The next great step was the invention and universal use of lightning-rods to protect buildings. Franklin, as a human lightning-rod, had challenged death in making one of the greatest discoveries and inventions possible to mortal man. Fourteen months later, a physicist at St. Petersburg, Russia, having put up a plain iron rod to collect the electricity of the heavens, and trying to read the indications of an "electrometer," forming part of his apparatus, was hit by a globe of blue fire from the rod, which killed him as swiftly as would a bullet from a pistol. The truth is that Franklin's is one of the most remarkable cases of good luck on record.

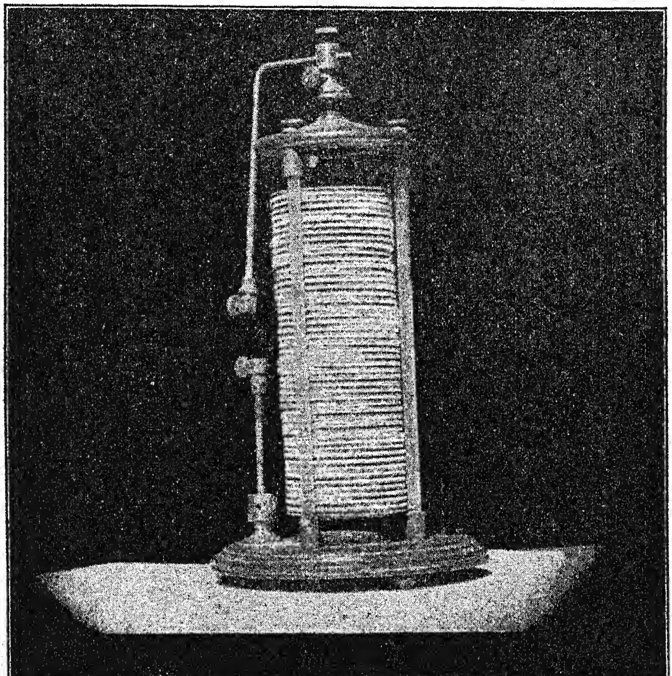
It must be clearly understood, however, that the Thales, Watson, and Franklin kind of electricity is of little practical value or use, except in radio. We cannot light electric lamps, run trolley-cars, or work electric motors by sparks from rubbed glass, or even by captive lightning. The great tasks that electricity now performs for mankind need a steadily flowing stream of energy; in other words, a current. And we now proceed to narrate how the current came to be generated and applied.

The Discovery of the Electric Current

Luigi Galvani could hardly understand why Franklin wanted to toy with the thunder-clouds when electricity was all around and even in us. Although his reasoning was profound, Galvani was seemingly unable to apply it successfully. The Italian physician, father of modern medical electricity, was one of those men who try to find out more than books can teach them. In order to get a better understanding of the human body, he studied the muscles, nerves, and bones of birds, frogs, and other small animals. He was keenly interested in

electricity, and of course had a friction-machine, similar to the one used by Franklin. He also knew that the "electric eel" and other fishes could give a severe shock.

One day, in 1786, Galvani was working over the legs of a skinned frog, when an assistant started to spin the electric



Courtesy General Electric Company.

THE FIRST ELECTRIC CELL.

Volta's first battery or voltaic "pile," made in 1800, consisted of a number of silver coins and equal number of zinc disks of the same size. The silver and zinc disks were piled alternately on top of one another, with pieces of moist cloth between the disks. Wires were fastened to the top and bottom of the pile, and when they were joined, Volta obtained a steadily flowing current of electricity. Thus did electrical engineering begin.

machine which stood on the same table. The dissecting knife Galvani was using happened to touch one of the wires of the machine. Instantly the frogs' legs kicked in the most lifelike manner. This gave Galvani an idea. "If an electrical charge can make the legs of a dead frog act as though they were alive," he thought, "they must have been charged with electricity

when they were alive. Therefore, electricity must be the thing that makes us live."

If this were true, it was indeed a most important discovery. Galvani became eager to prove it. During the course of one of his experiments, he fixed the legs of a frog to a copper hook and hung the hook on an iron railing. But no sooner had the two metals come into contact than the legs kicked vigorously. Here was something even more extraordinary. This time there was no electric machine around. Why did the legs kick? "Because," said Galvani, highly delighted, "these legs are so fresh, they are still full of electricity! My theory is correct!" He immediately wrote a book on the subject, and soon frogs' legs were kicking in every laboratory in Europe.

Most of the scientists who thus amused themselves believed what Galvani told them. But there was one man who tested the truth of everything for himself. This was Alessandro Volta, who taught science in the Italian University of Pavia. In 1789 he studied this strange kicking very carefully, and gradually made up his mind that the electricity was caused by the contact of the two different metals, and not by the frog.

Galvani was very angry. "You are wrong!" he wrote to Volta. "I have proved that electricity is life."

"I am not wrong," replied Volta, "and I'll prove it by producing electricity with metals only, and *without* frogs' legs!"

Volta then took a number of silver coins, made an equal number of zinc disks of the same size, and piled them alternately one on top of another, with pieces of moist cloth in between. He fastened wires to the top and bottom of the pile, and when he joined the two wires together, he produced, for the first time, a steadily flowing *current* of electricity. This he accomplished about 1799.

Why an electric current should be produced by the contact of two different metals we do not as yet know. But that it is produced in this way, can easily be proved. Touch the underside of your tongue with a silver coin and the upper side with a steel key. Then bring the outer parts of the coin and the key together. You will notice a distinctly sour taste that is different from the flat taste of either metal by itself, and your tongue will tingle for several minutes afterward. This sourness is

caused by a feeble electric current, which flows when two different metals are placed in contact with moisture. Volta's "pile" was the first electric battery. It is one of the most important inventions ever made, for it gave us the electric current. It aroused little interest, however, and when it was demonstrated to the great Napoleon he was unable to see any value in it, though its power was infinitely greater than that of his whole army.

Volta's pile was soon greatly improved. Everybody imitated it for purposes of experiment and research, and a considerable number of different kinds of batteries were invented. These batteries opened up an entirely new field of knowledge, and discovery quickly followed discovery.

One of these discoveries was the ability of the electric current to break up certain substances, such as lime, which no chemist had been able to analyze. In this way a number of previously unknown chemical elements have been obtained in their pure state, one after another, down to this day. Electro-chemistry is one of the great new arts thus founded.

The Relation between Electricity and Magnetism

The electric current was a link, like the Panama Canal, between two great oceans: electricity and magnetism. These vast realms the electric current joined and converted into one inseparable body.

Human acquaintance with the effects of the lodestone, or natural magnet, is as ancient as the knowledge of the properties of amber. Magnetic iron ore, or magnetic iron sand, may be found in all parts of the world, and the appreciation of its mysterious power seems always to have been common. Sir Isaac Newton, the discoverer of gravitation (the magnetic pull that all the heavenly bodies exert upon one another through space), had a finger-ring in which was set a three-grain magnet that would lift 700 grains of iron. Long before the science of magnetism was academically established, the corroborative fact had been observed that magnets had polarity.

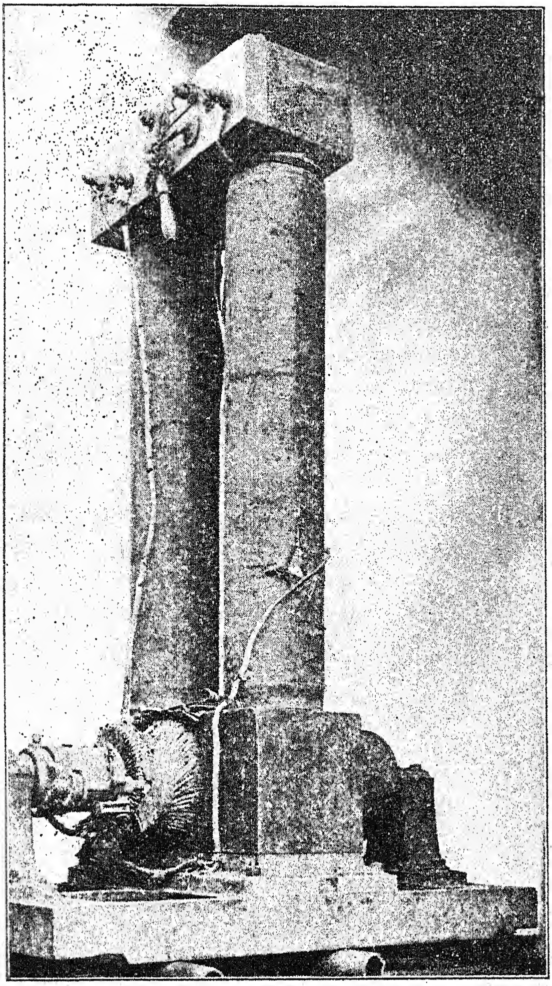
At least a thousand years ago, sailors depended on the use of the compass, a noble invention of the highest rank. An iron needle that had been rubbed by a natural magnet was put on

a pivot, or floated in a bowl of water, so as to swing around, indicating north and south, as well as east and west, when it came to rest. Easy to falsify, one who tampered with it, if detected, met a punishment that fitted the crime; his hand was nailed to the mast, or he was "keelhauled" under the ship, or thrown overboard. The Dutch mariners added the familiar point-card to the compass. Columbus, who without the help of his compass would never have discovered America, noticed that it did not always point exactly to the true north. His solution was that the needle had not received the proper magnetic rubbing; but in this he was wrong. For the most part the theories of the magnet and the compass were mere guesswork in those days, and no real ideas or inventions of profound importance came for two hundred years. The best of the investigations were those of the English physician, Gilbert, about 1600, whose splendid work, *De Magnete*, was an addition to scientific research. Progress, however, was slow until the immortal discoveries, in 1819, of Hans Christian Oersted, professor of natural philosophy in the University of Copenhagen.

There was such a similarity between the separate accomplishments and properties of electricity and magnetism, that it would have been curious if, by 1800, somebody had not guessed they were closely related. Hans Christian Oersted, with grim determination and patience, set out to prove it. He was a rather clumsy experimenter, but possessed with the right idea. Even though his magnetic needle did not at first respond to the flow of current from a voltaic cell, he stuck to his discourgaing task. Finally, in 1819, he and his students went wild with joy and excitement when they saw Oersted's magnetic needle spin round as the circuit was opened or closed. There was good reason for celebration. Oersted had slaved for this success for thirteen years, and it stimulated philosophical investigation to the highest degree. When Faraday, in 1831, made a wire conveying a current revolve around the poles of a magnet, he also celebrated his discovery, rubbing his hands in glee, skipping gaily about the table, making holiday the rest of the day, and winding up with a night off at Astley's Circus to see the performing horses.

It should be noted that Oersted did not really invent any-

thing. Apparently he did not care to, preferring "knowledge as his highest aim." But his splendid discovery was seized upon with avidity by all the scientific men of the world. In-



Courtesy General Electric Company.

EDISON DYNAMO OF 1883.

ventions and other discoveries came thick and fast. As Faraday said, Oersted had "opened the gates of a domain in science, dark till then, and filled it with a flood of light." This was indeed an achievement for one who at twelve years of age

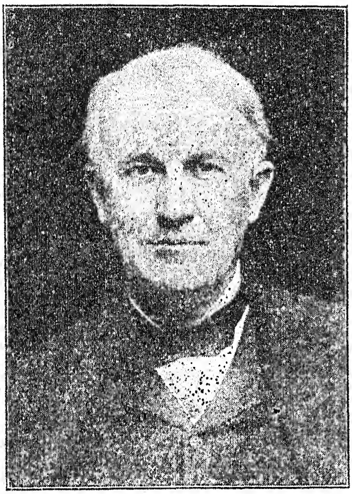
had been an errand boy in a little apothecary's shop on a small island in the Baltic Sea.

Within a few months, that metaphysical genius, Ampère, had seized upon the inner meaning of the work done at Copenhagen; and between 1820 and 1828 he founded the great workaday science of electrodynamics, by laying down its laws and predicting some of their applications. It is only right that the very unit of electric current should be named after him; for Ampère soon proved that all the phenomena of magnets, action and reaction, pull and push, revolution and polarity, could be repeated with coils of wire through which an electric current was passing—and all the more emphatically if iron was put within the coils. He also showed that currents themselves behaved like magnets, and indeed were magnets. Arago, another great French philosopher, in 1820, had invented electromagnets. He discovered that if he wrapped a live wire around a small bunch of iron wires, the wires became magnets, and stayed magnets as long as current flowed in the wire. Davy, to whose great work we are soon coming, also discovered independently the power of the electric current to magnetize iron and steel, and so helped set the stage at the Royal Institution in London for the magnificent performances of his pupil and successor, Faraday. Before leaving behind Ampère in this swift advance, it may well be noted that, like Thales and Franklin, he also had strong political democratic tendencies. South American patriots visiting France found a warm welcome in Ampère's pleasant Parisian home, and, next to electromagnetism, nothing stirred him more to red-blooded enthusiasm than discussing the heroic feats of Bolivar and Canaris in creating new republics out of the wrecks of Spanish dominion. Ampère was never ashamed of telling the story of his early years. When only thirteen he read a paper before a certain society in which he solemnly informed the learned members how they could square the circle!

Arc-Lights and Dynamos

About this time the Royal Institution in London, founded by an American in 1800, became the home and work place of two very notable men. Its creator, Count Rumford, was a

plain Massachusetts Yankee, Benjamin Thompson, but the fortunes of the War of Independence carried him to Europe, where his genius and ability soon made their mark. The ruler of Bavaria engaged him to manage the royal arsenals. Being a real philosopher, he took the opportunity, while boring a cannon, to prove that heat could be produced by mechanical



Courtesy General Electric Company.

(Left) THOMAS ALVA EDISON.

(Right) WILLIAM STANLEY, INVENTOR OF THE MODERN TRANSFORMER.

Edison was the first to supply electricity commercially. To him is due the whole modern system of generating current in a central station and distributing it to homes and factories.

power. He also taught the Bavarians many arts of peace, and was soon made a count of the Holy Roman Empire. Going back to England, where he had also been created a knight, he secured the charter for the Royal Institution, and chose a clever young Cornishman, Humphry Davy, as lecturer and director of the laboratory.

Davy, whose widowed mother was a poor milliner, became apprenticed to an apothecary-surgeon, and taking up chemistry as a study soon discovered that the properties of pure nitrous oxide, "laughing-gas," were respirable and had the power to lessen physical pain, the beginning of modern anæsthetics. Electricity also interested him, and his originality justified

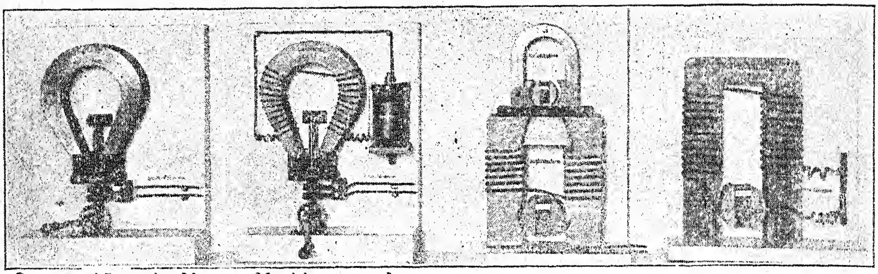
Rumford's selection of him as a Royal Institution lecturer. In electrical annals Davy stands out distinctly in the white glory of his own arc-light, with which his name is associated, and he was one of the most distinguished precursors of the electrical engineers of to-day. Passing the current from a powerful battery which had no fewer than 2,000 plates dipped in acid solution, he secured intensely brilliant illumination from the consumption of two sticks of charcoal. This was in 1808. He called it an "arc" light because the little blue-silvery bow of light formed an "arch" as it wavered between the glowing pieces of carbon rod. With his giant battery, Davy was also able to isolate metallic potassium and sodium; and although France and England were at war, the French Academy magnanimously recommended Davy as the first recipient of the gold medal promised by the vigilant Napoleon for the "best experiment that should be made in each year on the galvanic fluid." But the world owed him another gold medal for discovering and befriending no less a genius than Michael Faraday, the Columbus of electromagnetic induction.

Born of humble parents in a remote suburb of London, Faraday had practically no school education. The facts of his early life and how he attended Sir Humphry Davy's lectures in natural philosophy is told in the chapter on "Radio Communication." To young Faraday those clever lectures by Davy had far more fascination than his work in a bookbindery. Faraday's initial scientific task was the unpleasant one of extracting sugar from beet-roots; and it was succeeded by something even more disagreeable, the manufacture of stinking bisulphide of carbon. Even that did not discourage him, nor the fact that, when he went abroad with Sir Humphry Davy, in 1815, Lady Davy, socially ambitious, refused to dine at the same table with one whom she regarded as the equal of her husband's valet.

On Christmas Day, 1821, the young wife of the laboratory assistant was invited by her husband to leave the simple domestic part of the stern old Institution where they kept house, and share his delight over a wonderful new experiment. All she saw was a small vase nearly filled with mercury, into which a tiny copper wire dipped. On the mercury floated a little bar

magnet, held by a thread to the bottom of the vessel. Now, the wire was in circuit with a "voltaic" battery, and every time the circuit was closed to the mercury, that floating bar, like a chip in a swirl of tide, revolved around the wire. No simpler way could be devised of producing a continuous regular mechanical motion from the action of an electric current. Faraday always stripped his demonstrations down to the barest elements. Ten years later, before the Royal Society, in 1831, Faraday described his "new electrical machine," first of many millions that since have embodied the same vital, cardinal idea. His "dynamo" consisted essentially of a disk of copper, twelve inches across, mounted to rotate between the poles of a big permanent magnet. Two collecting brushes, one resting on the axis hub of the wheel and the other on its rim, carried off the current generated as the revolving disk cut through the unseen "lines of magnetic force" of the permanent magnet. Thus was mechanical motion converted into electrical energy; and then by successive stages Faraday, in 1831 and 1832, developed the phenomena of electromagnetic induction, the basis of all our modern dynamo-electric machinery, generators, and motors. Moreover, he showed that his "induced" current had all the earmarks of the "voltaic" battery current, and then by an ever-memorable series of experiments he went on to prove that all the electricities are the same: static, dynamo, magneto, voltaic, thermo, animal, etc.—just as all men belong to the human family. Other important discoveries followed, for which there is no room here. Faraday lived a life worthy of one of the world's greatest scientists. Bence Jones, in his *Life and Letters of Faraday*, wrote: "His was a lifelong strife to seek and say that which he thought was true; and to do that which he thought was kind." Long before he died the world had begun to reap wonderful harvests in his "fields of magnetic force" and from all the great electromagnetic arts that are now "human nature's daily food."

William Sturgeon, in England, shared with Arago, in France, the credit of making the first electromagnets. Joseph Henry, in America, shared with Faraday the credit of the first demonstrations of the new principles of induction, magnetic repulsion and attraction. Then, in 1832, came the vanguard of inven-



Courtesy of Deutsches Museum, Munich.

a. Saxton (1833). *b.* Wheatstone (1845). *c.* Wilde (1861). *d.* Werner von Siemens (1866).

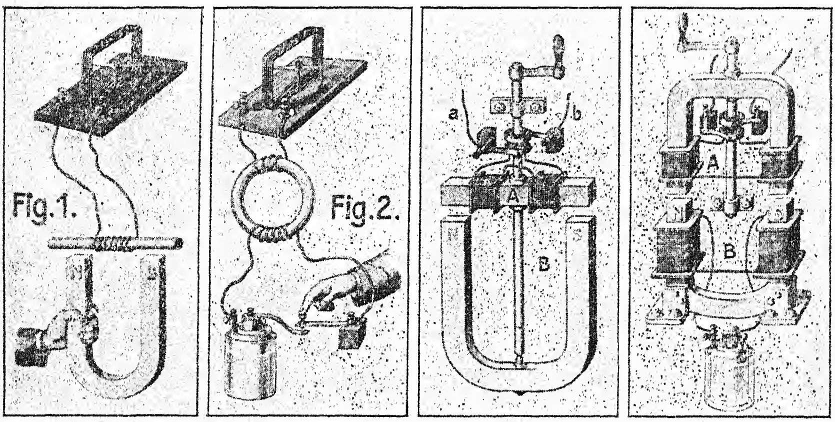
EVOLUTION OF THE ELECTROMAGNET.

a. Two coils of wire rotate in front of the poles of a steel magnet. The induced current is conducted to the line by a brush or collector.

b. In order to obtain more powerful magnets Wheatstone used electromagnets which were excited by galvanic energy.

c. In order to obtain more powerful electromagnetic effects without the aid of a galvanic current Wilde used a small auxiliary machine and steel magnets to generate energy for the electromagnets of the main machine.

d. Von Siemens used the residual magnetism of an electromagnet to induce a feeble current in the armature. This induced current augmented the magnetism of the electromagnet and was itself augmented until the electromagnet was completely saturated.



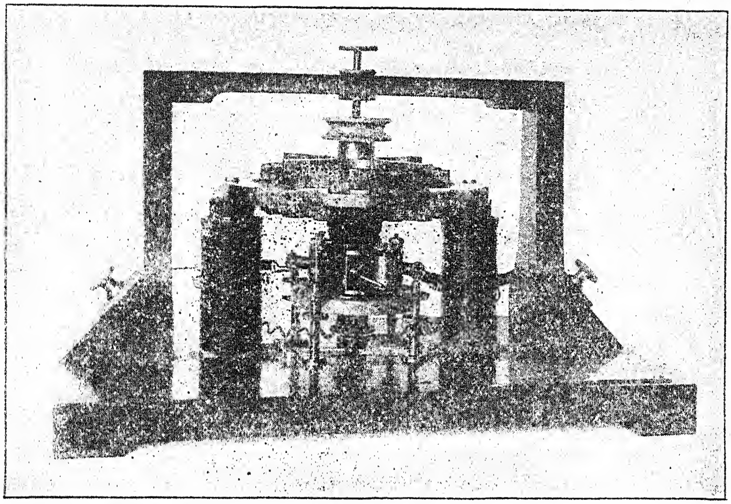
Courtesy of Deutsches Museum, Munich. 3. Pixii (1832). 4. Wheatstone-Cooke (1845).

THE GENERATION OF ELECTRICITY BY MOVING WIRES NEAR MAGNETS.

1. In 1831 Michael Faraday discovered that an electric current can be induced in the iron core of a wire coil when a steel magnet was moved toward and from the coil.

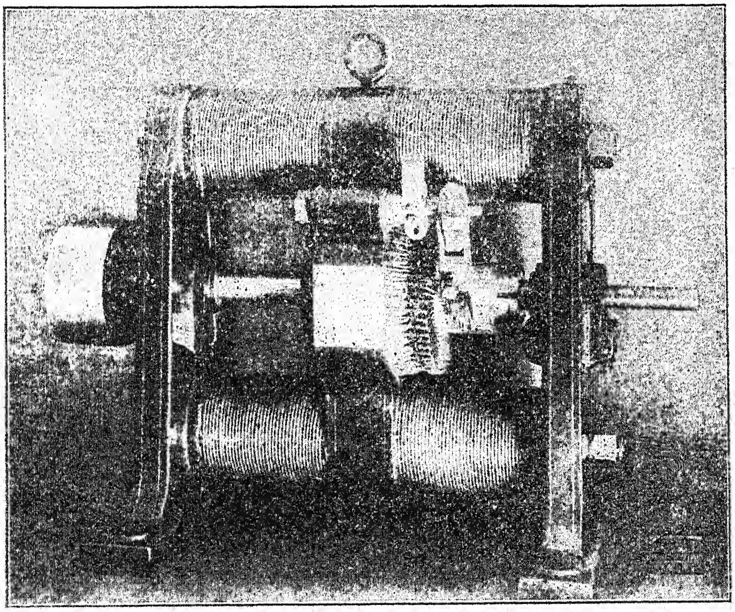
2. In the same year Faraday discovered that electric currents can also be induced in a coil when a near-by coil is electrified or de-electrified. These induced currents were most powerful when both coils had a common ring-shaped iron core.

3 and 4. Historic magneto-electric machines. (3) The coils *A*, provided with an iron core, rotate in front of the steel magnet *B*. The electric current induced in the coils by the alternations of magnetic effect in the iron core is collected by the brushes *a* and *b*. (4) The coils *A* rotate with their iron core in front of the electromagnet *B*. The electromagnet *B* consists of an iron core wound with wire through which flows the electric current obtained from a galvanic element. Thus the iron core is magnetized. The magnetic effect is greater and hence a more powerful current is obtained.



Courtesy of Deutsches Museum.

REPLICA OF PACINOTTI'S DYNAMO OF 1860.



Courtesy of Deutsches Museum.

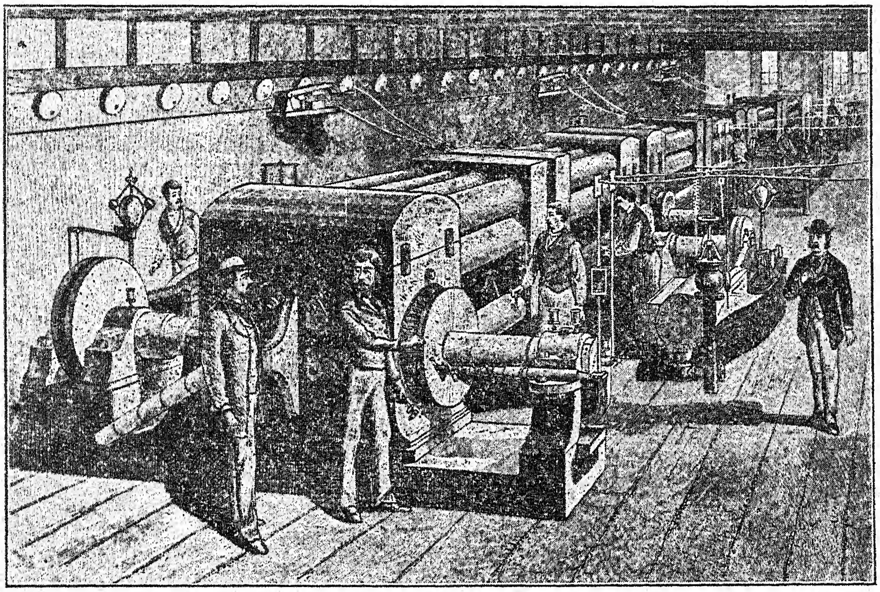
ORIGINAL RING-ARMATURE DYNAMO OF GRAMME (1870).

tors, headed perhaps by H. Pixii, a Frenchman, who began with the invention of magnetos with coils of wire spun around in front of permanent magnets, and later produced "dynamos" in which, instead of permanent magnets, they employed electro-magnets, using some of the "self-exciting" current from the machine itself. This was a great stride forward, and, in 1860, Doctor Antonio Pacinotti devised the first dynamo to give "continuous" current, all in one direction, or of one sign, + or −, in place of the "alternating" current which reversed itself incessantly, as in the machines of Varley, Wheatstone, and Siemens. Next came the famous Belgian, Z. T. Gramme, who in Paris, 1870–72, produced the first practical generator yielding absolutely continuous or direct current. Adopting the soft iron ring of Pacinotti, the Italian professor of vine culture, this master mechanic wrapped around it consecutive lengths of insulated wire, thus forming a number of short, distinct coils, whose ends were brought out to a commutator. Like a series of pipes all leading out one way, each coil as it passed in front of the magnets squirted out its little discharge of current through the commutator ring of copper strips, and that current, of positive sign, could be used for all the innumerable purposes to which continuous or "direct" current is now applied.

How the Electric Motor Was Accidentally Invented

Up to the time of Gramme, people had built electric motors to be operated by current from batteries; then machines to generate current, first for electric lighting and then for electro-plating with copper or silver. It was a case of putting the cart before the horse. The dynamo should have come first. But at an industrial exhibition in Vienna, 1873, a number of Gramme dynamos were being set up as exhibits. In making the electrical connections to one of these machines, not yet belted to the shaft of the driving steam-engine, a careless workman by mistake attached to its binding posts the ends of two wires already connected to another dynamo actually in operation. It was the sort of mistake that often happens in an electrical plant, when "hooking up" the machinery. To the intense astonishment of everybody looking on, the armature of the second machine at once began to revolve with great rapidity. When

the attention of Gramme was directed to this highly novel phenomenon, he saw that the second machine was functioning as a motor, with current from the first, and that what took place was an actual transfer of mechanical energy through the agency of electricity. With that remarkable incident began the period of the great modern use of the electric motor for power and do-



THE FIRST CENTRAL STATION.

Built by Edison and the nucleus of the present Edison Company. It was opened for operation in 1882. This picture is made from a contemporary print in the *Scientific American*.

mestic purposes, and the development of the art of electric-power transmission, which, in turn, led to the vast water-power utilization of to-day.

Separate chapters in this volume deal with the arts and inventions in electric lighting, electric traction, and telegraphy and telephony, all of which depend for their current supply upon current taken directly from dynamos or from storage batteries whose chemical reactions enable them to deliver the "stored" energy when it is needed, and when the dynamo is out of operation. We shall confine ourselves here to a brief note of some of

the other fields of electrical application developed since the days of Pacinotti and Gramme, and mention a few of the "star performers," to whom a leading share in such utilization must be credited.

Applications of Electricity

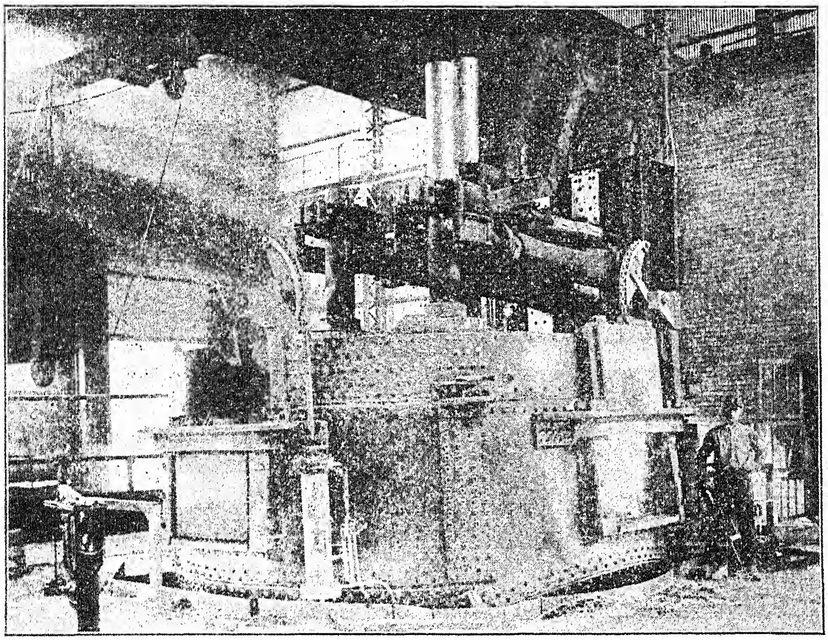
With the invention of the dynamo or generator came the possibility of electric illumination. How the arc was developed by Brush and the incandescent lamp by Edison is told in the chapter "From Rushlight to Incandescent Lamp." Both Brush and Edison saw that the dynamo would have to be vastly improved if houses were to be lit by electricity. To Edison belongs the credit of having devised the modern system of generating current in a central station, and supplying it to houses by wires fed from mains. Lamps, dynamos, fuses, switches, all the paraphernalia with which we are now so familiar are his creations—the work of the early eighties.

Edison had barely got his incandescent-lighting system introduced, Brush had not yet finished refining his famous arc-lighting system, and Sprague was at the beginning of his electric-motor development,* when the outward urge of all this expansion necessitated some device that would enable central-station plants and electric-trolley railroads to cover larger areas of service from the one source of current supply. It was found in the "transformer" and the alternating current, to which George Westinghouse, inventor of the air-brake, devoted nearly all of his life after 1884.

To understand the transformer, we must go back to Faraday's discovery, made in 1831, when he wound two coils of wire on a soft ring of iron. When he shot current through one coil he saw by the galvanometer needle in the circuit of the other that "induced" current was flowing in it also. That is about all we do with the modern transformer, which in its various forms is simply Faraday's induction-coil. About 1884, an erratic Frenchman named Gaulard, backed by a sporty Englishman, Gibbs, showed with a crude "secondary generator," or transformer, that current could be sent miles and miles. The

*See the chapter on "Electric Cars and Trains," p. 106.

device was like a spring-board or a catapult. Low-pressure current could be put through it in large volume, and, by induction from one coil to the other, could be raised in voltage for long-distance transmission over a very small wire. Conversely, if the alternating current thus raised in pressure was to be used at low pressure, it could be put through a "step-down" trans-



Courtesy General Electric Company.

TWENTY-TON HÉROULT ELECTRIC FURNACE.

Siemens conceived the idea of melting steel commercially by means of the electric arc. The Frenchman Héroult did much to make this idea practical. This Héroult furnace is used by the Carnegie Steel Company. The annual production of electrosteel throughout the world is now 1,500,000 tons.

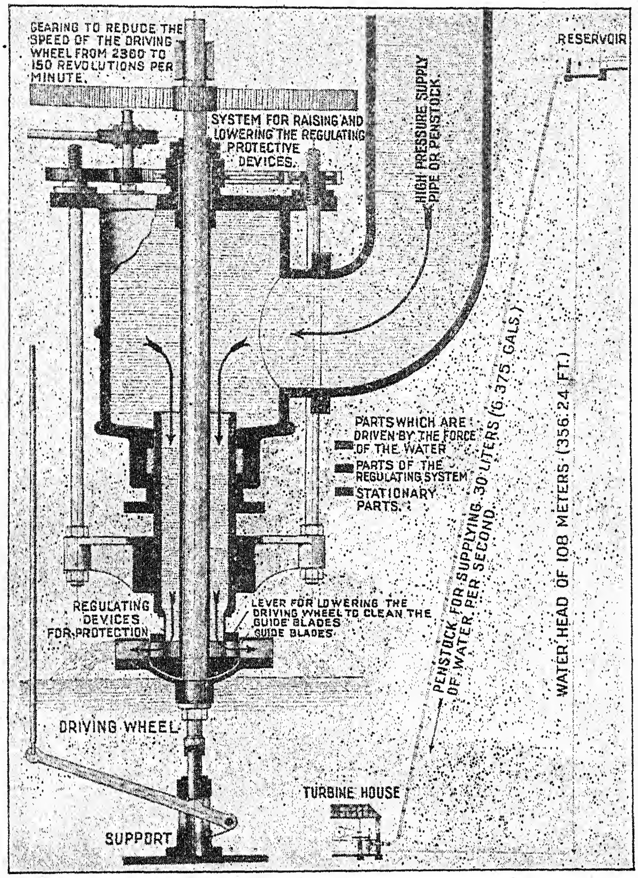
former at the consumption end of the line, by being received by a fine wire coil, and lowered in pressure and increased in volume by the big wire coil alongside it.

A very brilliant young engineer from the Berkshire Hills of Massachusetts, William Stanley, Jr., took hold of this crude appliance and soon worked out the transformers that were to be the prototypes and forerunners of all those in use in America to-day. Erecting a little laboratory workshop in his native

Great Barrington, he gave that town the honor of being the first to illustrate the momentous new departure in electric light and power. The first large alternating-current station was installed by Westinghouse, using the Stanley transformers, in Buffalo, New York, the same year, 1886.

All this early alternating-current work was done with what is called "single-phase" alternating current. Few such generators are made to-day. The first alternating dynamos were "single phase," so were the first transformers, and their chief virtue was this ability to annihilate distance, although they had many drawbacks. Away on the Serbian borderland of eastern Europe was born, in 1857, a genius, Nikola Tesla, son of a clergyman in the Greek church. The Serbians have had little time to give to invention; their task has been the guarding of the Balkan Mountains, the preservation of their little country; and in their language there are a hundred words for knife to one for bread. As a young student at Graz, Austria, brooding, imaginative Nikola Tesla saw and ran a Gramme dynamo, and with quick intuition he decided that the commutator and brushes were not necessary. Forthwith, he began a career that soon brought him to America, there to invent what is now world-wide in name and application, namely the "polyphase" system; two-phase or three, the latter perhaps predominating to-day. The first power transmission of Niagara energy began with the Tesla two-phase apparatus built by Westinghouse. Tesla went on to develop other ideas and inventions employing high frequency currents, and thirty years ago he began to demonstrate the wireless transmission of signals and power, becoming the pioneer of all the "broadcasting" now so familiar and fascinating. He also showed many incandescent-lighting effects in lamps without filaments and unconnected to any circuit, and took the first photograph ever secured by fluorescence and phosphorescence—the light of the firefly. At the time of writing, this temperamental genius was still hard at it in the very centre of the "wireless" stage.

Of a different type is Doctor Elihu Thomson, who spent all his vastly productive life in America, to which he was brought when only a few years old by his skilful father, a north of England machinist. Thomson's development of "repulsion phe-



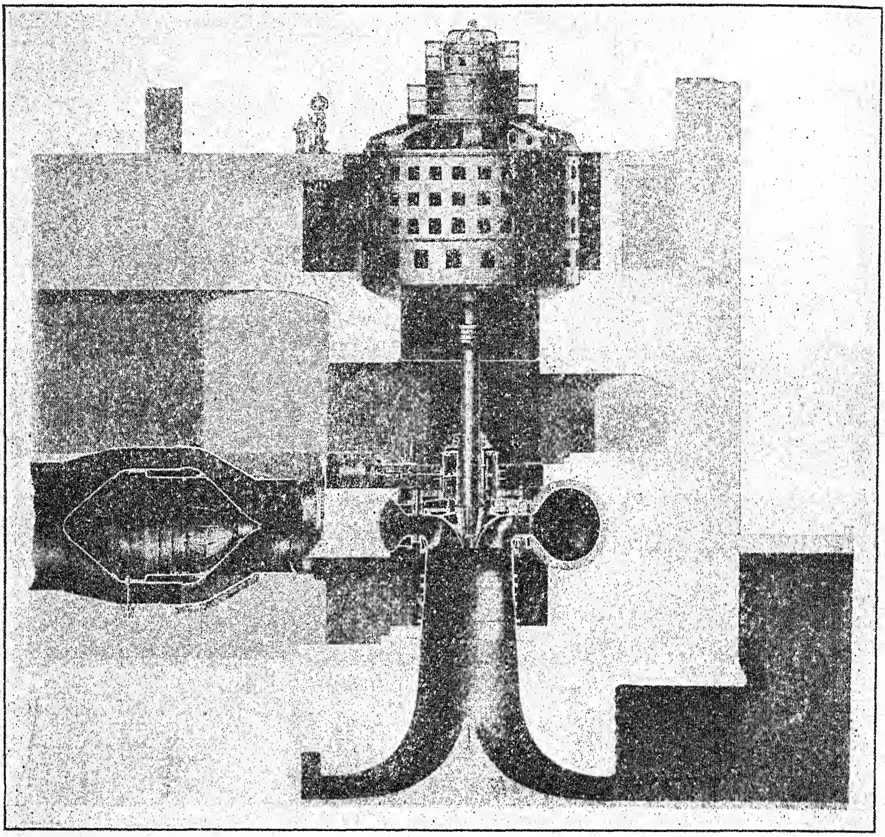
Courtesy of Deutsches Museum, Munich.

SECTION THROUGH THE FOURNEYRON WATER-TURBINE OF 1834.

Foruneyron's water-turbine in its earlier forms had a vertical cylindrical chamber with a side inlet for the water and a central pipe below, through which the water passed to an annular outlet at the base of the pipe. This outlet was fitted with guide-blades which directed the water tangentially as it escaped. Surrounding this passage was a driving-wheel, keyed to a vertical shaft and provided with vanes between which the water flowed as it passed from the inner to the outer circumference, where it was finally discharged.

nomena" became the basis of several useful arts, but he might prefer for special mention his creation of the great modern industry of electric welding. Lecturing at the Franklin Institute in Philadelphia, he noted that in one of his experiments the wires of a Ruhmkorff spark-coil had been welded by the instantaneous discharge of a heavy current. With the swift vision of

genius, he glimpsed at once the possibilities of electric welding. In 1885, he worked the whole process out, and made the first electric welds that finally became the basis of the enormous



Courtesy William Cramp Ship and Engine Building Company.

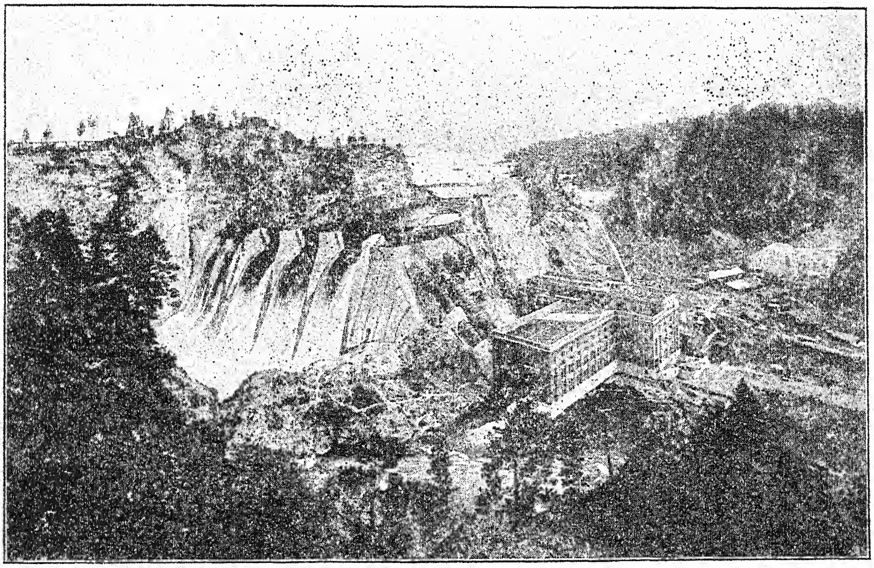
PART OF NIAGARA'S HARNESS.

Section through one of the 55,000 horse-power units for the Niagara development of the Hydro-Electric Power Commission of Ontario.

extension in welding now seen everywhere in the most varied of arts, from wire-manufacture up to the making of hulls of battleships and ocean liners.

A similar new art has grown up out of electrodynamics in the use of the electric furnace. About 1877, that great German pioneer, Siemens, conceived the idea that it should be pos-

sible to melt steel commercially by means of the electric arc. He took a crucible, bored holes in the sides, stuck electrodes through the holes, started an arc, and melted steel by radiation. Since then a vast variety of such furnaces have come into use, "not because the electricity plays any peculiar part in the process, but simply because they furnish a convenient means of



Courtesy General Electric Company.

MODERN HYDROELECTRIC PLANT.

The dam which backs up the water is clearly visible; so are the penstocks and the power-plant itself, to which water is supplied by the penstocks.

obtaining very high temperatures which can be easily controlled"; temperatures up to 6,500 degrees Fahrenheit. A French chemist, Moissan, specially distinguished himself by work in this field, dealing with refractory substances. In 1893, he actually produced diamonds from common graphite. True, they can barely be seen, unless you look at them under the microscope, but some day artificial diamonds may upset the market for precious stones and compete with nature's output from the mines of South Africa.

Meantime, the electric furnace is invading the whole field of metallurgy. At the beginning of 1920 no fewer than 900

electric steel-making furnaces were in use throughout the world, with an annual production of 1,500,000 tons. But there are also very many electric furnaces for the non-iron metals, such as brass, aluminum, and copper.

In 1881, chancing to hear a remark of a famous gem expert on the value of abrasives, a young American, E. G. Acheson, born in Washington, Pennsylvania, and then only twenty-five years old, set to work along original lines. To him is due the world's most widely used artificial abrasive, carborundum. He was only sixteen years old when he started work in his father's blast-furnaces; then, in turn, he became a surveyor's chainman, a railroad ticket clerk, a worker in the iron mines, and eventually a draftsman for Edison. Under that great inventor's supervision, Acheson helped in the early perfection and introduction in America and Europe of the incandescent-lighting system; he finally became an inventor on his own account.

In 1891, with an ordinary solder melting-pot for a furnace, Acheson, experimenting with high temperatures in the hope of producing artificial diamonds, and using sand and ground coke for the charge, accidentally obtained "carborundum," a silicide of carbon. It was a positively new substance and an important abrasive. To-day, with the help of electrical energy from Niagara, millions of pounds of this compound are produced annually. Acheson continued his experiments in an incandescent furnace. One day, after overheating the furnaces, in which, like Moissan, he actually produced minute diamonds, Acheson noted a black substance with a greasy surface. It was graphite. Once more a whole realm of electric metallurgy and chemistry was opened up. Acheson next proceeded to divide this artificial graphite by "deflocculation," thereby grinding it up about as far as mechanic processes can go, and discovered a new series of lubricants. Kindred researches have carried Acheson far into the electrical manufacture of clays, fine crucibles, and into several other arts.

The chapter, thus far, has dealt but slightly with electrochemistry, or "electrolysis," which includes the arts of electroplating and the refining of copper—most American copper now being thus heated to secure very high purity. A large part of the electric current generated at Niagara Falls is thus employed

in making bleaching powders. In much the same way a very persevering American, T. L. Willson, made calcium carbide, from which is obtained the illuminating gas called acetylene, an account of which discovery will be found in the chapter, "From Rushlight to Incandescent Lamp." Most notable of all has been the extraction, from very ordinary earthy substances, of the metal aluminum, so vital to many industries, such as aviation. Before American inventors, such as the Cowles brothers and Charles M. Hall, put their wits to work in 1886, aluminum sold at four dollars a pound and was hard to get; but after they and Héroult, the Frenchman, had developed their processes and "baths," it could be bought in ingots like pig iron at only twenty cents a pound.

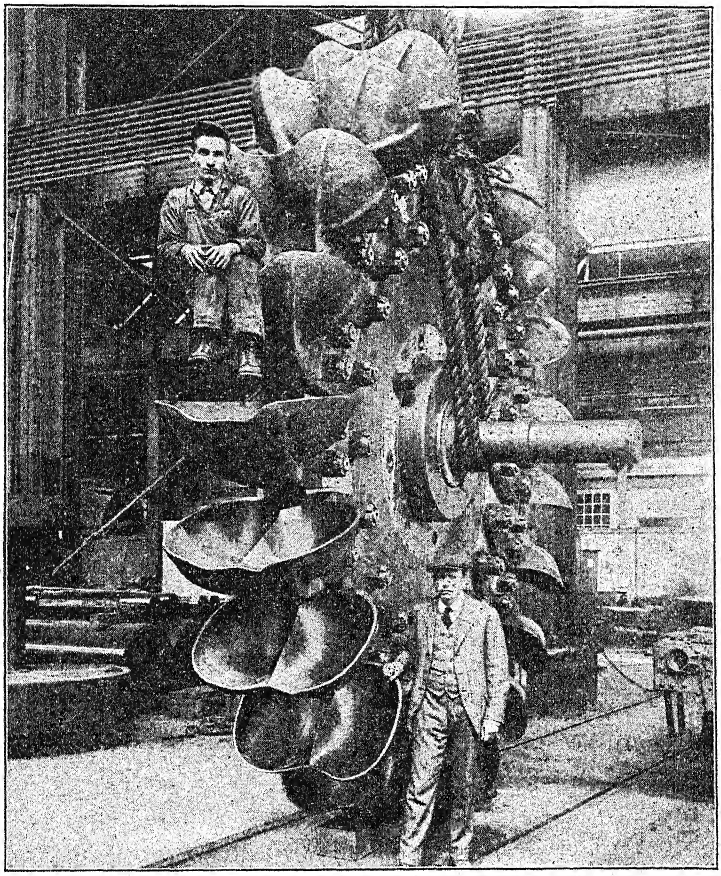
This work brings us into another great field of modern electrical development, that of electric heating and cooking, particularly for domestic purposes. Benjamin Franklin, in 1747, proposed an "Electrical Dinner" when a turkey was to be killed by electric shock, and roasted by the electric jack before a fire kindled by the electric bottle. But it was more than 150 years later before the prophetic fancy passed into a commonplace actuality. In 1891, an Englishman, H. J. Downing, gave an exhibit of his "radiant heat" electric-cooking appliances at the Sydenham Crystal Palace. Before that nothing really worth while in electric cooking had been invented. Four years later, a young American, W. S. Hadway, devised a little plant for cooking, which instantly proved practicable. The equipment consisted of an oven, small portable stoves, "spider," plate-warmer, coffee-pot, and teakettle. In 1896–97 Hadway installed an electric range in the Fifth Avenue mansion of Andrew Carnegie, New York city. Within a few years many inventors and manufacturers were in the field, and in 1920 the production of electric ranges in the United States exceeded 40,000, from some eighteen producers. But the electric ranges are only one of a group of such electrical appliances now made and used in America. There are more than fifty varieties on the market, in the purchase of which for use in the home the public spent no less than $175,000,000 in 1919. Associated with all these articles that lessen enormously the burden of housekeeping and the need for domestic servants, is another

ingenious group of appliances such as electric vacuum cleaners and washing-machines, all helped in adoption by the fact that whereas the cost of nearly everything has gone up enormously in the last ten years, the price of electric current has steadily gone down.

Millions of these ingenious and useful devices due to American inventors are now produced yearly, but probably none more numerously than the universal fan motor, by which our civilization furnishes itself with cooling breezes in summer and heated currents of air in winter. The punkah coolies of India and fan-bearers of all the Eastern world are outmatched by this little American device. In 1904, the Franklin Institute awarded to Doctor Schuyler S. Wheeler its John Scott gold medal for his invention of an electric fan, reduced to practice in 1886. Wheeler, who had to struggle very hard to complete his education at Columbia University, secured a position with the first Edison electric light company, started in New York in 1882. While working he and his great chief, Edison, slept in the famous Pearl Street station, on cots set up right alongside the steam-engines, so that they did not leave the plant for several days and nights. Later Wheeler became a maker of small electric motors, and it occurred to him that by increasing the "shaft height" and by turning upside down the type of motor made to run sewing-machines, a little wind-blowing propeller could be hitched on—and there was the fan motor! Useful fan motors are now countless, and Wheeler proceeded to "fabricate" millions of horse-power in industrial motors, equipping notably some of the largest American steel works for "electric drive."

It is now a rare day that does not bring news of yet another electrical invention or application. No sphere of life is left untouched. "Behold, I make all things new" is the inspired Scriptural phrase that might be applied to this renovating influence. A late discovery is the electrolytic waterproofing of textile fabrics, by the process of A. O. Tate, a brilliant young Canadian engineer, once private secretary to Edison, for whom, as an expert telegrapher, he did original work. In developing storage-batteries and electric filters of his own, Tate came to the conclusion that by means of electric current he could im-

pregnate fibrous materials with a water-repelling substance. Thus he manufactured a fabric not only water-proof, but mildew-proof, and of a higher grade of quality. The process was



Courtesy Allis-Chalmers Company.

TWENTY-FIVE-TON WATER-WHEEL.

Pelton wheel for the 30,000 horse-power units built for Great Western Power Company's Caribou plant, California.

first installed in Montreal, Canada, in 1916, and operated by an Imperial Commission. In July, 1920, the celebrated Cranston Print Works, Rhode Island, were equipped for an output of 30,000,000 yards per annum of electrolytically waterproofed and electrically "converted" fabrics. Cottons and woollens

alike gain by the process, as do most of the clothes we wear; duck and canvas for sails and tents are also now largely treated in this way; wall-papers that can be washed with a hose are another group involved in changes so novel and comprehensive that the mere term "waterproofing" is inadequate to describe them.

Electricity and Water-Power

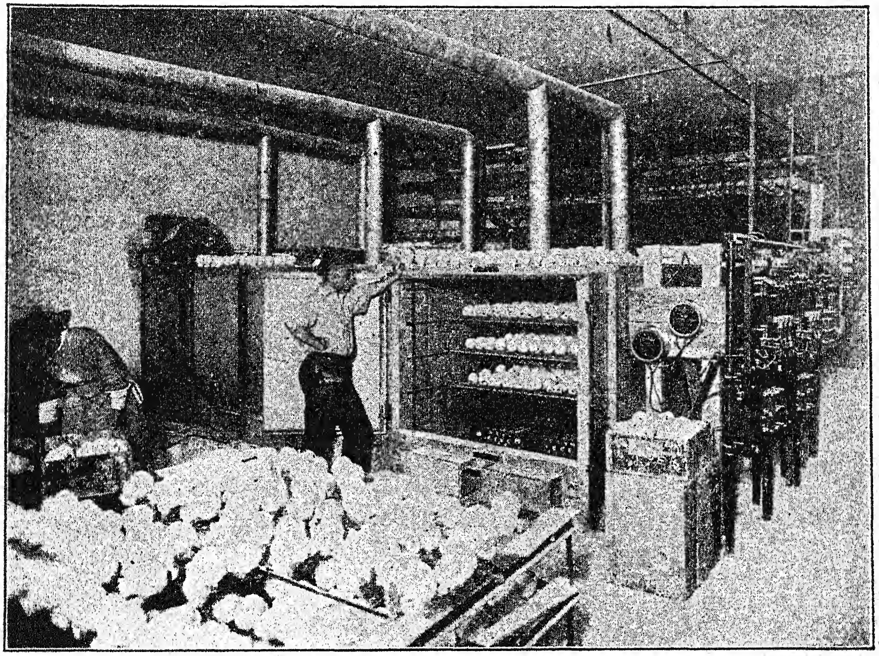
It is remarkable that books on invention and the encyclopædias have so little to say about water-power or wind-power. The reason for this is probably that no really first-class inventor has ever associated his name with modern adaptations of the very ancient devices that depend on breezes or falling water. There is, of course, a large amount of literature on hydraulics, but the student will hunt in vain for enough books on wind-power to fill a five-foot shelf, even if he include treatises on sails for ships.

It is not likely that the march of mankind in the path of civilization was governed in any way by the local prevalence of steady currents of air to drive windmills; but it is known that, next to having access to water for drinking, our forefathers valued running water for its ability to furnish power for their primitive industries and later on to operate small factories. Even then they depended just as largely on animal-power or the muscular effort of human beings. To this day, in old Asia, teams of men are still employed to do the sort of work which in America is more easily and smoothly accomplished by the electric motor.

For present purposes wind-power may be forgotten; but to the Hollander it is very necessary, practical, and useful. There are, however, very few dynamo-plants driven by wind-power. The wonder is that more do not exist, especially where coal costs twenty dollars or more a ton, where water-power is scarce, and where currents of air like "trade-winds" are almost as dependable as the rising sun or the turn of the tide. Some day, also, electricity may be generated more or less directly from the sun's heat, which after all is what moves the air and the water.

The history of the development of water-power and its ap-

plication to general use has been concomitant with that of electricity. Flowing water can spin a wheel with a breast or frontal attack; it can drop on the wheel from above; or drive it with an underflow. The principle, the same in each case, is plainly illustrated by our domesticated white mouse and squirrel when they tread their tiny paddle-wheels and merry-go-rounds in a



Courtesy General Electric Company.

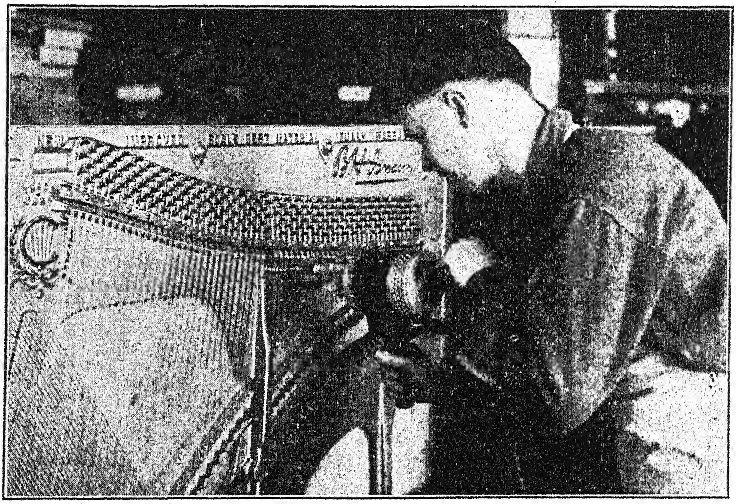
ELECTRIC OVEN USED FOR BAKING DOLLS' HEADS.

cage. In ancient times water turned a mill-wheel, thereby revolving clumsy millstones, between which were ground wheat and other necessities for human consumption and maintenance. But many years went by before it was realized that a wheel steadily turned by water-power provided a continual source of energy that could be used in several different ways.

The water-turbine, upon which our great, modern hydroelectric plants depend, had its beginning in 1827. In that year, Benoit Fourneyron, a young Frenchman of twenty-five, winning a prize offered in his native country, gave the world the modern

turbine water-wheel, in which water is received not outside but inside the wheel it drives. There have been subsequent additions to his invention, many exceedingly valuable improvements coming from such Americans as Howd, Francis, Morris, and others; but all have been as edifices built upon the foundation of Fourneyron's original idea.

Once the way was discovered, the United States with her natural aptitude for invention and development lost little time



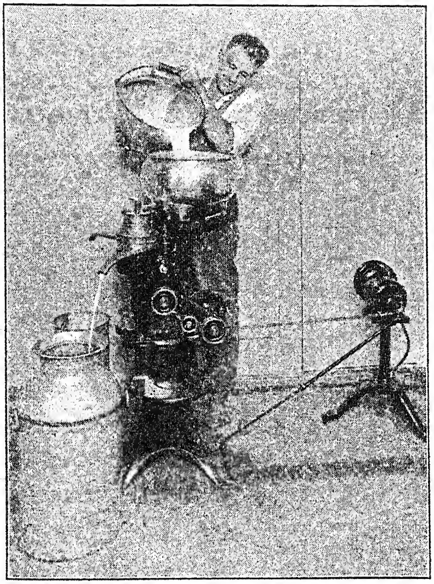
Courtesy Van Dorn Electric Tool Company.

ELECTRIC AUGER DRILLING HOLES IN A PIANO FRAME.

in making good use of water-power. Europe, perhaps with lesser facilities for practice, remained somewhat behind. Not many years ago on the River Adige, in Italy, the writer witnessed barges out in mid-stream getting their feeble power from the torrent that came down from the remote mountains. It is now easier to lead the torrent to the turbine than the turbine to the torrent. Man's ingenuity has made water-power act as his slave. He has forced water to fall into buckets around the rim of a wheel, or, as in our modern turbine of various types, shot it through the middle of the wheel.

The famous Pelton water-wheel, invented and developed in 1884, proves what can be accomplished with cups or buckets around the periphery of a wheel. Pelton, a plain Ohio carpenter,

ventured out to California during the gold-fever days of the "Forty-niners." There he saw more wealth in water-power than could ever be extracted from the placers and the rocks. His water-wheel plant, draining the waste surface waters at the Chollar mine on the Comstock Lode in the Sierra Nevadas, was hitched to a Brush 130-horse-power dynamo. After having first driven another electric generator on the surface, the buckets



Courtesy Society for Electric Development.

MOTOR-DRIVEN MILK-AND-CREAM SEPARATOR.

on the wheel were forced into whirlwind speed by water falling into them from a height of over 1,600 feet. A jet of water from the directing nozzle smashed into the twin cups at a speed of many miles an hour. With the current thus obtained, six electric motors, each of eighty horse-power, were operated in the Nevada stamp-mill more than a mile away. No more convincing proof could be desired of "high-head" hydroelectric power. The Comstock Lode has long since lost its value and glory; but the wealth of its water-power will probably never be exhausted.

One of the advantages in using water-power is that it is

power saved, and not wasted, as it is with coal. By skill and good luck, the electric lamp, motor, or cook-stove may get six to ten per cent. of the energy from burned coal to run the steam dynamo; ninety per cent. of the whole energy is irrevocably lost. With hydroelectric power, at least six to ten per cent. is saved of what was previously a hundred per cent. loss in available power; all the coal is saved, because the water is still on hand. This great economy of power was demonstrated by the Pelton water-wheel.

Water-turbines have rendered possible all that is now going on in electric-power transmission. The hydroelectric utilization of Niagara for transmission of current to long distances began in 1895 with units of 5,000 horse-power. To-day there are six electric power-producing companies at the Falls, and the latest plant, at this date has in operation three turbine units of 37,500 horse-power each. But while such power at Niagara is transmitted at 60,000 volts pressure, voltages twice as high are in use elsewhere, and 300,000 volts is a potential talked of as glibly and confidently as was 10,000 twenty-five years ago.

The total possible water-power of the world is computed at about 450,000,000 horse-power at low water. For millions of years this vast power, greater than that possessed and dreamed of by kings and dynasties, has flowed freely, placidly, and uninterruptedly to the seas.

The United States mines annually about 700,000,000 tons of coal, and the supply must sooner or later give out. Water-power, if developed to the highest degree, would furnish more energy yearly than a billion tons of coal, although it can never supply all the electrical energy needed. Hydroelectric development alone has now made it feasible and profitable to use nearly all of this tremendous power in the years to come. Water-power electrifies the great railway systems of the world; it lights San Francisco and Los Angeles with current from the snowy slopes of the Sierras, about 300 miles away. In fact, hydroelectrical energy will help to keep our lamps and wheels going until physicists learn to break up atoms and thus open up new stores of pristine power from "founts that ne'er can run dry."

CHAPTER III

FROM RUSHLIGHT TO INCANDESCENT LAMP

WHEN man learned how to make and handle fire he began to improve it as a source of light. In some of the ancient caverns, scientists have found niches or shelves dug and chipped into the rock walls, in which fires had been built for lighting purposes only.

Man began to choose various kinds of wood and rushes which would burn more brightly and last longer than those which he needed merely to make heat for cooking. He found that the grease from roasting meat gave a bright light. He also used the fatty parts of the bodies of birds or fish as torches. Splinters of certain woods, as the pine, were found to burn steadily without much smoke. Still better light was obtained by soaking the splinters in oils and waxes procured either from animals or berries. Then the marsh-rush was peeled, and its pith soaked in readily burning fats or waxes. Thus came into use the rushlights, which were used in illuminating theatres in the days of Shakespeare and became picturesque symbols of the dramatic art and of the gay night life of cities. There is a line in Addison about the old beau caring more for the smell of the rushlights than for that of the country hedges in the coming of the spring. The peasants of Scotland burn rushlights to this day.

Those first adventurers of the high seas, the Phœnicians, who appear to have been everywhere and to have done everything, invented the wax candle, which they made either from the pressed honeycomb of the bee or from substances obtained from plants and berries. This was long before the Christian era, and much earlier than the invention of the tallow candle, which is placed at 200 B. C. Spermaceti, a fatty substance obtained from the sperm whale, was introduced into candle-making about 1750. Paraffin was not obtained until after the discovery of petroleum. It is now much employed for candle-making; although candles are used to-day mainly for decorative effect.

For centuries, the candle was a leading source of light. The overhead racks on which it was placed in large groups were called chandeliers or candle-bearers, and the name still clings to such fixtures now employed for gas and electricity. The grand ballroom in the king's palace was made brilliant by candles shining from chandeliers containing glass prisms, from which, when the candle-light shone through them, were reflected all the colors of the rainbow. At a reception given to Washington in Philadelphia, the hall was lighted with 2,000 candles.

Courtesy General Electric Company.

BEFORE THE DAYS OF STREET-LAMPS.

As late as the eighteenth century linkboys carrying rushlights guided wayfarers to their homes and made the streets not too safe from footpads.

Brilliant as this ceremony must have been, the lighting was dim compared with that in a modern store. Even when other and brighter lighting methods were being introduced, as keen an inventor as Count Rumford, an American whose surname was Thompson, could not at first see that there would ever be any better illumination than candles. Whether as the simple tallow dip, made by dipping a wick into successive baths of the hot grease, or waxed and moulded about the wick, the candle, in all its forms, remains an inconvenient source of light. It requires constant wick-trimming or snuffing, and the attention it demands is always more or less of an annoyance.

The Evolution of the Lamp

The lamp, fully as old as the candle, and by some historians considered older, was for centuries no more satisfactory than the candle. It is likely that primitive man gathered bear

grease in shells or in the skulls of small animals and burned it by putting into the fuel a wick made of pith or rush fibre. It was not a far cry from these rude dishes to the flat earthware saucer used as a lamp by the ancient Egyptians. The inner chambers of the great Pyramids were finished by slaves working by the open flames of such oil-lamps. The oil-lamp was flicker-

METHOD OF MANUFACTURING TALLOW AND WAX CANDLES IN THE EIGHTEENTH CENTURY.

ing when Moses wrote the Tables of the Law, and Confucius his immortal maxims. By the same kind of lamp Cæsar, in the century before Christ, planned his campaigns against the Gauls.

Vegetable oils and the greases were later displaced by whale-oil. At first the inhabitants of New England and Long Island were content with the carcasses left by the tide upon their shores. Then as the demand for whale-oil increased, vessels were equipped to pursue the big mammals into the North Atlantic Ocean. The skippers of the New England coast, especially

those who hailed from New Bedford, Salem, and Nantucket, made fortunes from slaying the whale at sea and trying out his blubber into oil. The trade was extended later to the Arctic circle, and so much destruction was wrought in the eighteenth century by the efforts of the hardy Yankees to supply the world with oil for lighting, that the race of the monsters of the deep was in danger of extinction.

It was at this point in the history of illumination that the first important discovery in lamp-making was made. Even the best lamps were smoky and smelly; a disagreeable odor permeated the air because of the rankness of the liquids burned, and incomplete combustion threw off waste products in the form of smoke and soot. For centuries men devoted their time and skill in ornamenting the outside of the lighting vessel and making artistic and beautiful patterns; shades, reflectors, and shields of various kinds were brought into use for both lamps and candles; but while artists vied with one another in the making of mere forms, the great problem of the proper combustion of the lamp fuel was left unsolved. Various dangerous fuels, such as camphene (a mixture of turpentine and alcohol), were introduced. During this era of perfecting the oil-burning lamp, it is small wonder that some of the staid old families were glad to cling to candles. Candles could be depended upon, and at least would not explode and bespatter the home with blazing fluid.

Genius gave the new impetus with the coming of Aimé Argand into the field of illumination. Argand was born in Geneva, 1755, of Swiss and Italian parentage. He had studied chemistry and physics in Paris, and on his return to his native Geneva he devoted himself to studies in distillation. His experiments with lighting grew out of his laboratory work. He wanted a flame with more heat.

If more heat could be obtained, the particles of matter, as they burned, would glow with greater intensity. So Argand by making the burning more complete, consumed all the smoky vapors and made them glow in unclouded brilliancy. To do this he, as a chemist, got more air (oxygen) into the flame. This he did by devising a circular burner into which was fitted a round wick, instead of the usual flat one. The air entering

into the flame fanned it to greater intensity, and the light grew more dazzling. To steady the flame Argand placed a perforated metal chimney an inch or so above the blazing wick. This made a still better draft. Thus, in 1782, began the new era in lighting of which the herald was Aimé Argand.

It is generally accepted that Quinquet, a French druggist, of Paris, added the lamp chimney of glass as a substitute for the metal one. There is a story that the lamp chimney resulted from the accidental breaking of a tall, round bottle which a workman had placed over the flame of an Argand burner. The bottom falling out, the bottle fell over the flame, and, settling there, steadied the flame. Quinquet, at least, is credited with having made a chimney which was drawn in at the bottom, and thus helped strengthen the draft. According to some, Argand believed that his invention had been stolen from him, and he was thereby driven insane. The story is manifestly untrue, for in 1785 Argand had described his device in great detail in the French *Journal de Physique*.

Carcel, a contemporary, added a pumping arrangement for getting the fuel oil up into the wick. He did much to popularize the Argand burner for street-lighting. It was really not until after Argand died in 1805 that the full importance of his discovery dawned upon the world.

The Introduction of Gas-Lighting

It was at this period that there came gradually into use a new and powerful means of lighting, the value of which had been quietly developing for nearly two centuries. Even the ancients had known that there issued from the earth certain gases which burned, but it was not until burnable vapors were made artificially that a revolution in the art of illumination was achieved.

In 1667, Thomas Shirley, a landed proprietor of Lancashire, something of an amateur scientist, wrote a small book in which he described a well at Wigan from which issued water supposed to burn of itself. He had found the jet surrounded by groups of rustics who suspected that it was some trickery of the devil. Investigating, he found, and proved, that it was not the water

but a vapor which came from the earth at that point and which caused a flame "when a candle was approached to it."

The Reverend Doctor John Clayton, Dean of Kildare, made an examination near the same point, and was convinced that the vapor had something to do with the coal-mines in the neighborhood. So he put some lumps of coal into a retort and applied a good fire. At first there came off what he called "phlegm,"

From a photograph of an old painting. By courtesy of W. and T. Avery, Ltd.

Courtesy Consolidated Gas and Electric Company, Baltimore, Maryland.

(Left) WILLIAM MURDOCK.

It was William Murdock who first taught Englishmen the possibilities of coal-gas as an illuminant. He illuminated his own house with gas in 1792.

(Right) THE MAN WHO LIT LONDON BY GAS.

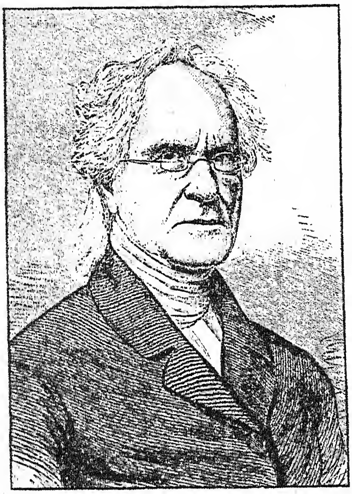
F. A. Winsor, the romantic and not too truthful promoter who introduced gas-lighting into England on a commercial scale. It was of him that Sir Walter Scott wrote: "There is a madman proposing to light the streets of London—with what do you suppose—smoke!"

then some black oil, and finally a "spirit," as he termed it in 1691, which "spirit" he could in no wise compress. This vapor he gathered in bladders, and when he pricked one of them with a pin and applied a lighted taper, there burst from the tiny hole a jet of flame! He showed his discovery to a group of his friends.

A Dutch scientist, Van Helmont, early in the seventeenth century, in making experiments with fuels, had noted that when

heated in closed vessels, they gave off this same wild spirit which had been experimented with by the Yorkshire divine. Van Helmont called it a "geist," or spirit, a word which in time became "gas" in nearly every tongue.

At the venerable University of Louvain, in Belgium, experiments had been made in driving vapors from heated wood,



(Left) REMBRANDT PEALE.

One of the sights of old Baltimore was "Peale's Museum," not unlike a similar institution later opened in New York by P. T. Barnum. Peale illuminated his museum with gas in 1816.

(Right) THE INVENTOR OF THE GAS-METER.

Samuel Clegg was one of the engineers who made gas-lighting practical.

and one of the professors of chemistry nearly suffocated his classes at times by demonstrating the existence of the "spirit" by turning it loose in his classroom.

Thus years before any practical application of the knowledge of the burnable gas was made, scientists knew something about it. It remained for William Murdock, a Scotchman, to show how this coal-gas could be practically utilized. Murdock, a splendid mechanic, was born in 1754, in Ayrshire. He was what we might call "queer," and this queerness, in one particular, led him to wear wooden hats. As an employee of Boulton & Watt, the steam-engine builders, he had been sent to install

machinery in the English coal-mines. While there his attention was drawn to the gases which were associated with the black fuel. He applied his engineering skill to the distillation of the vapor from coal on a larger and more practical scale than had ever before been attempted. In 1792, he succeeded in lighting with gas a house which he had rented, and then he piped the illuminant about the grounds and ignited it in the most approved manner. In 1802, he decorated and lighted the outside and the inside of his employer's factory near Soho, Birmingham, in brilliant fashion. The occasion was the celebration of the signing of the Treaty of Amiens, which ended the Franco-British war. Designs and letters were produced by the arrangement of iron pipes, in which were pierced small holes through which rushed the inflammable vapors. The gas was also employed in the lighting of large cotton-mills.

Phillipe Le Bon, a Frenchman, who got his gas from the distilling of wood instead of coal, was at about the same time making demonstrations of the new light source in Paris. There is no doubt that the erratic, clever Moravian, originally known as Friedrich A. Winzer, heard of gas first from the work of Le Bon. Winzer was the great-great-grandfather of all fly-by-night promoters; he had wit, energy, and imagination.

Selecting London as his new field, and adopting the more English name of Winsor, the "Get-Rich-Quick-Wallingford" of gas appeared. Winzer, or Winsor, had learned his lesson well. In Paris he had seen Le Bon ruined for lack of self-advertising. Although the gas made by Le Bon was poor in comparison with that of the present day, none the less he had been able to set in a blaze of glory the apartments and the grounds of the Hotel Seigneday. True, Napoleon had denounced the whole scheme of supplanting candles as "a grand folly," and the savants of France had therefore diplomatically refrained from indorsing the new lighting method.

This condemnation probably accounts in part for the fantastic and rather flamboyant methods employed by Winsor in attacking London, the English citadel of conservatism, with a new idea for public lighting. The rumors that vapors were to be employed as substitutes for candles had preceded Winsor. Sir Walter Scott wrote: "There is a madman proposing to light

the streets of London—with what do you suppose—smoke!" Even the noted British scientist, Sir Humphry Davy, put himself on record as opposed to this new-fangled means of illumina-

From a photograph by Consolidated Gas, Electric Light and Power Company of Baltimore.

EQUIPMENT OF A METER-MAN FIFTY YEARS AGO IN THE DAYS OF THE WET METER.

tion, asking if any one supposed that the dome of St. Paul's could be turned into a gasometer.

Winsor, on his arrival in England, made a drive in every direction in favor of his new means of lighting. He appealed to the latent curiosity of the people by giving exhibitions in private and by holding public lectures. Owing to the infancy of the illumination he advocated, he found it very hard to get

hold of competent assistants, and often his best-staged experiments failed. On these occasions, he gave way to bursts of temper which did not tend to inspire popular confidence.

But his assertions grew with the opposition. He calmly informed the Londoners that his gas would tan skins, smoke bacon, and fix colors in dyeing. When he got down to lighting proper, there was no limit to his flow of words, for his eloquence knew no meter. "As to illuminations," he said, "they may be carried on to the utmost extent of beauty and variegated fancy by this docile flame, which will play in all forms, submit to instant changes, ascend in columns to the clouds, descend in showers from the streets, walls, etc., arise from the water, even in the same pipes with a playing fountain."

The Londoners were sure that they would be poisoned if they got even a whiff of the vapor, but Winsor assured them that the day would come when they would be glad to cut holes in the pipes so that they might have the advantage of inhaling continually the gas "which is the most favorable thing imaginable for the health."

When his critics attacked him, Winsor responded with exhibitions (1803 and 1804), in the Lyceum Theatre, London. He was then using coal instead of wood and getting really a brilliant flame. By using various kinds of burners he gave the jets different shapes, a plan which justified him, he thought, in his statement that "their constant varying in rooms and gardens between flaming pyramids, festoons, garlands, roses, and flambeaux afford the spectator a most delightful sight, cherish the soul, and create good humor by united convenience, utility, and pleasure."

Winsor, early in 1807, moved his exhibitions to that fashionable promenade of London, Pall Mall. He lighted one side of the street with jets supported on posts, and to him therefore belongs the credit of beginning the system of public gas-lighting. It was a big progressive step which this loquacious genius had taken, for as late as the eighteenth century Londoners went to their homes after sundown accompanied by torch-bearers, known as linkboys, so that they might have protection against footpads. Lanterns were eventually placed in the windows of houses, and finally oil-lamps were introduced.

Although the lighting of the thoroughfares with gas seemed like a fantastic dream in those days, the idea was founded on the simplest facts. The flame of the candle is, in reality, a burning gas; for gas, after all, consists merely of finely divided particles of matter. Such particles are given off when the candle burns, and as they are consumed they glow with a brightness which produces what we call artificial light. A gas is emitted by burnable oils, especially oils easily evaporated. Samuel Johnson, long before the coming of Winsor to London, once saw an oil street-lamp burst into flame before the torch of the lamplighter had touched it, and with the insight of the prophet he said: "One of these days London will be lighted with smoke."

Winsor was so encouraged by the notice which he got for his exhibit in Pall Mall that he started to organize the National Light and Heat Company, and it is stated that he actually raised £50,000, or about a quarter of a million dollars to finance it. The money was nearly all wasted, however, in experiments. He had undertaken a task far beyond the times when he tried to make the gas on a large scale and to distribute it through pipes. Undaunted by his failure, Winsor, in 1809, applied to Parliament for a charter for a new company and tried to raise £200,000. Again the project was opposed as visionary and the extravagant claims of the promoter were used to defeat the application for a charter. It was at this point, too, that Murdock also fought the application, on the ground that Winsor was an impudent infringer. Parliament then passed an act protecting the makers of gas appliances from the competition of lighting companies.

The same interests which Winsor had marshalled, when they were again partially defeated, presented another petition, and three years later, 1812, an act was passed authorizing them to form their company. The police authorities of London, who had finally been impressed with the value of gas-lamps as a means of promoting the public safety, indorsed the project of the company. This new concern was called the London and Westminster Chartered Gas Light and Coke Company. Thus Winsor's idea was realized in a local rather than in a national organization, and experiments were carried on in many direc-

tions by the German inventor and others. Even then a leading chemist was singing the familiar tune: "It can't be done."

Lighting by gas seems so natural these days that it is hard to realize that the whole method of distribution—that is, the conveying of the gas through the pipes—was at one time held to be a daring enterprise. The people of London could not understand how it was possible for an "inflammable air" to make a fire and, at the same time, not white-heat the carrying pipes. Therefore there was much opposition to bringing the tubes into houses, and for a while the mains were exposed in the street and alongside the building line. Westminster Bridge was lit by gas throughout its entire length by 1813, and no accidents were reported. Lamplighters, who at first had hesitated to approach the posts from which the gas issued, were finally induced to take the risk. Since the task of putting in a distributing system and of overcoming the fears of the public was so urgent, the chartered company employed a competent engineer, Samuel Clegg. His attention was first attracted to gas when he was in the employ of the Boulton & Watt foundry, where also Murdock had been working when he illuminated the Soho building with gas distilled from coal. It was estimated that the piping of the Westminster district alone would cost £150,000, or very close to $750,000, a considerable sum in days when raw materials and labor were far cheaper than they are to-day. Clegg, a Scotchman and a very practical person, did not lose much time in finding out some way in which he could send gas-bills to the consumers. He devised and patented a gas-meter which was made of two large bladders, which were filled alternately with gas at a certain pressure and moved a mechanism which made a record on a dial. The valves of the apparatus were sealed with quicksilver.

To Clegg, in fact, belongs the honor of making the manufacture and sale of gas a commercial success. Although many improvements in detail have been made since the days of this able pioneer, the essential process remains much the same. Clegg, as chief engineer of the Westminster Company, supervised the construction of the first gas-holder in the world, and he was also the patentee of the first automatic pressure-regulating device.

So quickly is popular prejudice overcome, once it is made to yield even a little, that by 1816 gas-lighting was accepted as an every-day fact in the city of London. Paris was first lighted by gas in 1820. The French National Gas Company was projected in 1833 for illuminating the streets of Boulogne-sur-Mer and afterward taken over by the European Gas Company when its capital proved to be inadequate. Important French cities followed with plants for which the principal appliances were imported from England. For a long time Great Britain was the headquarters for the manufacture of machinery and meters.

How Gas-Lighting Came to America

News of the new lighting means had reached the United States. Public lighting by gas was first proposed on this side of the water in Philadelphia, in 1803, and the proposal was rejected as absurd. Again, in 1815, James McMurtrie suggested that the City of Brotherly Love try the new light source, but again the plan was dismissed. In 1806, David Melville of Newport, Rhode Island, lighted his house and grounds with coal-gas made by himself. His crude apparatus was patented in 1813, and used for lighting a cotton factory at Watertown, Massachusetts, in which he was interested. As far as is known, gas was first used to light a house at Providence, Rhode Island, in 1817; for in the little State where Melville was well known, his invention was much discussed.

Baltimore was the first American city to adopt gas-lighting on a large scale at the instigation of Rembrandt Peale, the artist and naturalist, a part of whose active professional life was spent in the old-time capital of Pennsylvania. Peale was the son of Charles Wilson Peale, also an artist, whose excursions in science had led him to found a museum in Philadelphia, which institution probably served as a model for that which Rembrandt Peale later established in Baltimore. One of the old sights of Baltimore was the venerable structure once known as "Peale's Museum," and now occupied by the city as the headquarters of one of its departments. In the Baltimore newspapers of June, 1816, there appeared an advertisement by Peale under a heading which at the time was nothing short of sensational. The caption read: "Gas-Light without Oil, Tallow, Wick, or

Smoke." Then followed a statement that "it is not necessary to invite attention to the gas-lights by which my saloon of paintings is now illuminated. Those who have seen the ring beset with gems of light are sufficiently disposed to spread their reputation; the purpose of this notice is merely to say that the Museum will be illuminated every evening until the public curiosity shall be gratified."

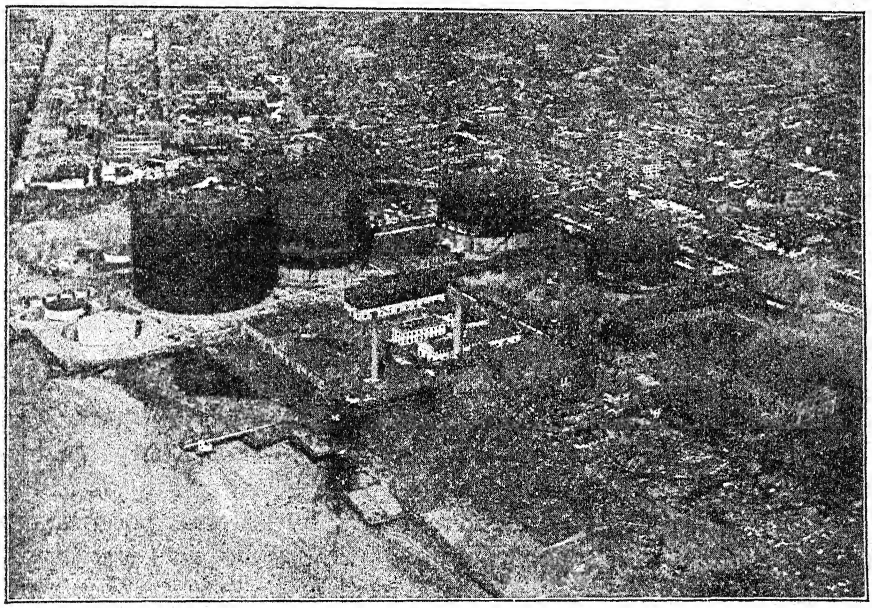
Peale, at the time, was busily engaged in painting the portraits of the prominent citizens of Baltimore, besides managing his museum. He had been in London and Paris about the time that Le Bon and Winsor were exploiting the newly found illuminant, and it is very likely that his circus methods of calling attention to the discovery were inspired by the original German promoter. The museum was, in some respects, not unlike one established in later years in New York City by P. T. Barnum, where the sensational and the scientific were strangely blended. Rembrandt Peale had much to do with disinterring the bones of mastodons in this country, and he treated those wonders of evolution and industry in much the same perfervid fashion as did the founder of what every one in the United States knows as "The Greatest Show on Earth." In the museum Peale delivered lectures on the wonderful illuminant which could be carried through pipes, and on the stage he had rigged various kinds of burners by which the form and the intensity of the flame were demonstrated.

Baltimore had another tremor a few weeks after the first display when it was proposed that the streets be lighted with the inflammable vapor. An editorial of *The Federal Gazette*, in July, 1816, said: "We are gratified in having an opportunity of communicating to the public. A proposition has recently been submitted to the Mayor by Mr. Rembrandt Peale, proprietor of the Baltimore Museum, to light the streets of this city by carburetted hydrogen gas; the very pleasing and brilliant light produced by that means the citizens have had an opportunity of witnessing for several nights in the saloon of paintings in the museum."

Official action followed close on the heels of this announcement; and on February 7, 1817, there was lighted the first gas-lamp in the city of Baltimore, and shortly thereafter the first

public building to be illuminated by gas in the city, the old Belvedere Theatre, which was opposite the original gas-works, was ablaze with scores of jets of the then novel vapor.

Boston granted a charter for a gas company in 1821, and in the following year actually had a plant for the manufacture of "inflammable air" in operation. The first demonstration of



Courtesy Consolidated Gas and Electric Company, Baltimore, Maryland.

AIRPLANE VIEW OF THE PRESENT GAS-PLANT OF THE CITY OF BALTIMORE.

the new gaseous fuel was made in the apothecary-shop of a Mr. Bacon, in State Street, and the public was so convinced by the "splendid appearance" made by the flame that before long the old city was agog over the wonderful new light.

Gas was introduced in 1823 in the city of New York by a company of which Samuel Leggett was the head. His dwelling at No. 7 Cherry Street, then a fashionable centre, and not far from the house occupied for a short time by George Washington during his first term as President of the Republic, was the first house in New York to be so illuminated. The old Knicker-

bocker families of that period were thrilled with the news that this strange illuminating agency had been introduced.

Philadelphia, however, continued to be a town in which the American prophet of illumination was still without honor. As late as 1833 a petition was addressed to her Common Council protesting against the use of gas, an article "as ignitable as gunpowder and as nearly fatal in its effects as regards the immense destruction of property." The conservatives believed that "this powerful and destructive agent must necessarily often be left in the care of youth, domestics, and careless people," and therefore they wondered that "the consequences of employing it had not been more appalling." Also, in view of the fact that the shad and the herring might be driven away by the discharge of the tar from the gas-works into the surrounding waters, the petitioners prayed earnestly that the lighting of the city with oil be continued. It was not until 1841 that Philadelphia, now the home of one of the most important gas companies in the world, was lighted with gas.

Baltimore, however, continued to hold its lead; for it was the first to use an important new form of the illuminant. To grasp the full meaning of that innovation, let us first review the essential points in coal gas-making, with which all of us are more or less familiar. The United States naturally soon began making its gas from coal although at first wood was employed. In New York City the first gas used was made from a resin brought from the South, and the gas conducted to the consumer in wooden mains, like those in which water was piped when Aaron Burr started the first water-works in New York. The apparatus for the making of gas from coal has, of course, been gradually increasing in power and size. As the illuminating product gained ground, however, the usual method was to feed great quantities of coal into iron retorts heated to about 700 degrees Fahrenheit by an outside fire. At this temperature, the coal begins to fuse and form gases. Several hours are allowed for this distillation; the gases being gradually forced out of the retort. The coal-gas is then refined by taking out certain harmful ingredients. In the retort is left coke, still heated to a white glow. A ton of coal thus treated yields about 10,000 cubic feet of gas, weighing approximately 400 pounds; about

three-quarters of a ton of coke; about one-twentieth part, by weight, of coal-tar; and fully as much liquid ammonia. The tar is of considerable value as a by-product. From it are made dyes, explosives, and medicines. The gas itself is washed by passing it through lime solutions and treated in various ways to get rid of any sulphur that may be present.

The hot coke which still remains in the retort can be used for the making of another form of gas, in accordance with a method introduced by Professor Thaddeus S. C. Lowe, who was for many years a familiar and picturesque figure in the streets of Baltimore. He was the American inventor and the chief promoter of "water-gas." It had been demonstrated by that distinguished French chemist, Antoine Lavoisier, who was executed during the Reign of Terror in the days of the French Revolution, that steam is decomposed by intensely heated substances. This is a simple scientific fact, but it took the alert brain of Professor Lowe to apply it to a successful commercial process. He and a Frenchman named Tessie Du Motay, quite independently of each other, conducted experiments which resulted, about the same time, in their application of the principle of Lavoisier to the making of lighting-gas. The method of Professor Lowe is now used by about seventy-five per cent. of the American gas companies. He passed the vapor of water in the form of dry or superheated steam through glowing coal. As water is composed of two parts of hydrogen and one of oxygen, the breaking up of its constitution made a new gas. The carbon and the oxygen combined to form carbon monoxide, akin to the marsh-gas which causes death when inhaled. The hydrogen is also set free. Although hydrogen is burnable, and indeed is a source of danger on account of its inflammability when used in the filling of balloons, it has scant illuminating power. It emits a pale-blue flame when ignited. Lowe enriched water-gas by spraying into it a partly refined petroleum, known as light oil, thus forming a vapor with a brilliant illuminating power. Vaporized in air, the blue water-gas and the oil constitute two gases which are really welded together by being passed through the heated chambers of the plant. The first chamber is the generator, where the coal or coke is heated white hot; the second is the carburetor where the combination with the

finely atomized oil is made; and the third chamber is the superheater, which is employed to fix or make more permanent the mixture of the two gases. Then comes the usual cooling and the purification, the washing and the storing of the water-gas.

Professor Lowe, a native of Norristown, Pennsylvania, was originally a balloonist, who was retained by the Union Army during the Civil War to make observations of the enemy from as high altitudes as possible. He used captive balloons, from which vantage-point he made sketches and photographs. Then, as now, hydrogen was the gas with which the bags of balloons were filled. He was not interested in getting a gas to burn, for if any other lighter-than-air and cheaply made vapor could be had in sufficient quantities, hydrogen would not be used long for either balloons or dirigible air-ships. Professor Lowe, who had considerable chemical training, knew about Lavoisier's discovery and used that knowledge for the making of hydrogen by the decomposition of water by heat. He established a miniature gas-works on the battle-field of Yorktown, and later at Fair Oaks, Virginia, and himself made many ascensions. At that time he had no intention of commercializing the process which he was perfecting, and naturally he did not introduce anything in his gas mixture to make it burn. That was the last thing he had in mind.

One day the professor made an ascent in his balloon, and when the fire opened upon him by the Confederates became too hot, he had the big balloon lowered. Among those who witnessed this incident was a sick man, William M. Cosh, who admired the courage of the aeronaut, and wondered, in an offhand way, where the gas was made that filled the balloon, for he had been somewhat interested in the illumination business in Philadelphia. After the war was over, the professor started to make a living by promoting the manufacture of water-gas, and Cosh became his partner in the enterprise.

Professor Lowe obtained his first patent for water-gas in 1873, and in 1874 set up his first peace-time plant at Phœnixville. The second plant, the one built at Conshohocken, Pennsylvania, in 1874–75, was developed on such efficient principles that it was literally a one-man plant; for Cosh made all the gas, set and read all the meters, made out the bills and collected them, did

the banking, and bought all the raw materials. The process was such a success that finally it was introduced in Norristown, the home city of the inventor.

The construction of the Baltimore water-gas plant was begun in 1877 by Cosh, and in January, 1878, the generation of gas was under way at the Canton station. Lowe's method proved such a success that it was soon adopted by many other large cities.

The Discovery of Welsbach

While the processes for the making of illuminating gases were being developed and cheapened, there was slowly forming a new art of lighting, which at last made a sweeping change in the industry. Thus far the light had come from a broad flame of the burning gas, either in the form of a fishtail or a cockspur. The next step was to use the heat of the blazing vapors to bring certain substances to a glow or incandescence, so that the light might be emitted from their particles. In 1826 Henry Drummond, a young army engineer in England, discovered that by heating a piece of lime to a high temperature by the burning of oxygen and hydrogen, the substance became incandescent, and gave out a brilliant light. The lime, of course, was not consumed, although in time it broke down under the intense heat and had to be renewed. Such a light was far too glaring for ordinary use. It was employed at first in making a coast survey of Ireland. Mounted in a magic lantern, it worked well for the display of picture slides, and eventually, as the "lime-light," it was used in the theatre. The invention of the Drummond light opened the way for a thorough investigation of all materials of high-melting points which might be employed on the incandescent principle.

The intense heat which can be obtained by forcing air into burning coal-gas, made possible still further progress on the road to incandescence. Robert Wilhelm von Bunsen, a professor in the University of Heidelberg, Germany, a noted chemist and physicist, in 1855 invented the burner which bears his name, and since then it has been possible to burn coal-gas with an intensely hot and smokeless flame. As he was the pioneer in the economical use of gas for heating purposes, his name

stands high in applied science. Every person who lights an ordinary gas-stove is putting to work a series of Bunsen burners.

Among the scholars who were attracted to the Bunsen laboratory at Heidelberg was a young Austrian, Doctor Carl Auer. Bunsen had discovered several rare elements. Auer turned to him for guidance in his own investigations of those remarkable materials which chemists call the "rare earths," and which are combinations of certain of the lesser-known elements with oxygen. These oxides of rare earths have always excited the curiosity and interest of scientists. Auer was a man of some wealth and aristocratic lineage. Next to delving into scientific matters, he was fond of fashionable attire and social pleasures. When plunged into his favorite pursuit, chemistry, however, he was blind to everything else. While studying the peculiarities of some rare earths, Auer was struck by the glare which came from them when they were held in the jet of a Bunsen burner. This spurred his inventive genius and urged him on to a discovery which later was to enable the gas industry to meet a grave crisis.

In experimenting with the rare earths Doctor Auer found he could get better results if he divided them more finely. He made solutions of them, with which he saturated pieces of cotton. He then put one of these little squares of cloth on a thin metal plate over the pallid blue flame of a Bunsen burner. The fabric burned up, but the rare-earth particles which remained clung together, so that they had the form of the cotton mesh upon which they had rested. In order to get a more uniform light so that he could study it to better advantage, Doctor Auer made a small cone of cotton cloth, which he suspended by a little loop over the flame, after he had soaked it in a strong solution of one of the rare earths known as thorium. Again the cloth was consumed and the chemical stood fused into a cone from which, as it glowed, there came a light of dazzling brilliancy.

Doctor Auer, from this point, dropped the merely scientific end of the rare-earth studies and worked night and day to get practical results. He put different kinds of rare earths on specially knit cones. These cones are known in Europe as "stockings" and in this country as "mantles." There had

always been plenty of rare earths for the limited demands of the chemical laboratory, but the doctor had to develop a means of getting a large enough supply of them for manufacturing mantles on a large scale. Mantles had to be made which also would stand transportation and would satisfy persons who were not skilled in laboratory practice. He made up some mantles of one kind of earth and after burning out the threads left

Courtesy Cooper-Hewitt Company. Copyright by Underwood & Underwood.

(Left) SIR HUMPHREY DAVY.

Davy experimented with the electric arc in 1801. There being no electric generator at that time, Davy obtained his current from a huge battery consisting of 2,000 cells.

(Right) THE LATE DOCTOR PETER COOPER HEWITT, WHO DEVELOPED THE MERCURY ARC.

them for a few days in a drawer. When he looked at them again he found that they had absorbed water from the air and dropped asunder. Still, by using such thorium as he was able to get, Auer made some fairly satisfactory mantles.

He then purified large quantities of the salt and found that the mantles made from it were very inferior as light-givers. This was discouraging. He had promoted a large company and sold stock and the investing public was getting suspicious. However, he began all over again and found that if his thorium was adulterated with about one per cent. of cerium, the lights

were perfectly satisfactory. By devoting months more of hard work to cheapening the materials, Doctor Auer, in 1885, got his burners into the markets of Europe and made them a commercial success.

The mantles were made to rest over a burner of the Bunsen type, and they also suggested the Argand lamp when they were aglow. For his distinguished achievements, the Austrian Government conferred upon Doctor Auer the title of Count of Welsbach, a name taken from his native town. In Europe his invention is still known as the Auer light. When the American rights for the invention were acquired in 1888, the company which took them over adopted the name Welsbach, which name, and not that of Auer, became universally known in connection with the new gas-mantles.

The handling of those strange metallic oxides, the rare earths, was developed by Doctor Harlan S. Miner, who as a young American chemist was sent abroad to confer with Doctor Auer. He was soon made chief chemist of the Welsbach Company at Gloucester, New Jersey. He rendered invaluable service by his researches, making distant journeys into the world in quest of more rare earths.

Had it not been for the introduction of the Welsbach mantle, the American gas companies would hardly have been able to meet the growing competition of electricity as a lighting agent. Gas of less candle-power can be used in heating up the mantle to a white glow, for high temperature is all that is needed. The intense radiance from the Welsbach hood was able to hold its own at comparatively low cost against the bulb which imprisoned the brilliant filament. The introduction of the Welsbach system of lighting also drew attention to a greater extent than ever before to the heating powers of gas; the cook-stove, the hotel range, and general industries called for still more gas fuel. In fact, the invention of Welsbach was a blessing in disguise for the gas companies.

The Story of Acetylene Gas

The story of gas would stop here but for the strange incidents which brought into the world of lighting an illuminating vapor from an unexpected source. There lived in the little town of

Spray, on the Smith River, in the farthest north of North Carolina, a Major J. Turner Morehead, a former officer of the Confederate Army. About 1890, he was trying to develop the water-power which he controlled at Spray, where he had an old cotton-mill. About that time there came from Canada Thomas L. Willson, who was trying to get some water-power for the purpose of working out a new process for making the metal aluminum from clays and earths. He had visions of conjuring bright pots and pans and other aluminum vessels out of the very ground. Willson proposed to use the clay called aluminum oxide, which could be obtained in that region, and to treat it with carbon in electric furnaces. The electricity was to be generated by dynamos driven by Morehead's water-power. Thus was born the Willson Aluminum Company.

Things went rather by sixes and sevens at Spray, for Willson was more of an inventor than a scientist. It was found that the process did not work out right, and Willson began to experiment wildly. He even used kerosene in the furnaces. Explosions and singeings were frequent. At last he announced that he was going to make some metallic calcium by heating coal-tar and lime together in the furnace. Major Morehead's son, who had been graduated from the University of North Carolina, was their chemist, and the young man had been in the habit of taking the fused masses of stuff which Willson prepared as they came from the furnace and plunging them first into a bucket of water before beginning his tests. He had burned his eyebrows from time to time and was wary. In May, 1892, when Willson was away, some of the mixture of lime and tar was being examined. It was noted that there came from the bucket a smell of sourish gas. "Maybe this is hydrogen coming off," suggested E. F. Price, who was looking after the scant finances of the company and therefore had leisure for observation.

Price got a piece of cotton-waste, soaked it in oil, put it on the end of a pole and lighted it. He then invited young Morehead to try the burning qualities of the vapor. The latter put the torch over the bucket and there came a brilliant flash and the familiar spiral effects of acetylene gas. The existence of the gas was known; it had been discovered in 1866 by the French scientist Bertholet. Its name means the "sharp or sour sub-

stance," and it was regarded merely as a curiosity of no value. The gas-producing substance which had been made in this haphazard way at Spray was calcium carbide, manufactured in an entirely new manner. Moissan, of Paris, had made a little, while engaged in some work with zinc, but never before had it been produced in such a way.

Meanwhile, with the new product on their hands, all concerned were practically penniless. Willson went north and tried something else. Price was glad to get a job as a locomotive fireman. Morehead managed to get to New Jersey where he was employed by the Westinghouse Company as a dynamo-tender. Willson came to see him one day about starting a company to exploit the new gas source, but his arguments were not convincing to Morehead, who had to lend him carfare. Major Morehead made two vain attempts to sell the process for $500. Finally, however, he did get hold of some money, and founded the Electric Gas Company. Then came the turn of the tide. A carbide company, which used current generated from the cataract, was started at Niagara Falls, and from it sprang the large corporation of the present day. Willson used up all his money in other experiments and died in poverty. Price became president of the carbide company, and the young chemist of the burned eyebrows, Morehead's son, was appointed its engineer.

Calcium carbide is a grayish-white solid, which, when dropped into water, causes the generation of the inflammable gas, acetylene. It is easily and cheaply manufactured, is much employed in welding and metal-cutting, and is favored by farmers who are unable to get electricity. There are about 300,000 rural acetylene installations.

Early Experiments in Electric Lighting

Simultaneously with the development of gas-lighting, slow progress was being made toward the practical use of electricity. Sir Humphry Davy, the noted English scientist, had discovered the arc-light in 1801, although he did not publicly exhibit it until eight years later. The dynamo had not come into the world, for which reason he employed as his source of current a huge battery consisting of 2,000 cells. There was the Wright

arc-lamp which was patented in England as early as 1845, and which consisted of five carbon disks. All the pioneers were bothered by the lack of means for generating a steady supply of current. One inventor, a youth named Starr, who lived in Cincinnati, is said to have worried himself to death over his vain attempts to fashion an incandescent lamp. After the appearance of the dynamo electric machine, experiment with the arc could at least be carried on in a more satisfactory manner.

Jablochkoff, an engineer living in Paris, invented in 1876 a crude arc-lamp which became known as the "electric candle." It consisted of two thin strips of carbon bound together but kept from actual contact by insulating material. The exposed ends of the "candles" were bridged by fine filaments of carbon, and when the current was turned on a brilliant light resulted. The "candles" were placed in globes, four to a twenty-inch receptacle, and glowed one at a time. The globes were not air-tight, and therefore the carbon was gradually burned up. Each "candle" lasted about an hour and a half, after which the current was switched to another.

During the Paris Exposition, in 1878, the Place and the Avenue de l'Opéra were lighted by the Jablochkoff candles. Each lamp was equivalent to several hundred candles; in various records their candle-power is given as anywhere from 285 to 1,500. Professor Silliman, of Yale, wrote from Paris that year of the splendor of the electrical illumination. "The effect," he said, "is magnificent, and at this moment there exists nothing in this city of splendid effects to compare with the magical scene. The vista is about two-thirds of a mile, and the effect incomparably finer than any show of artificial illumination ever before seen."

Although this first system of practical electric lighting was costly, it achieved popularity on the Continent and made some money for those financially interested. In the United States, however, it was regarded merely as a scientific curiosity.

Charles Brush and His Arc-Light

While Europe was working out the problem of the arc, a boy in Cleveland, Ohio, was making first toy dynamos, and then larger ones with which he could produce a current. He did not

like the gas-flames which lighted his own home, so he made some rods of coke and lampblack and syrup which he baked in the kitchen stove. He connected two of his rods, or electrodes, to his dynamo by wires. He then touched the carbons gently together at the ends and separated them, thus making an electric arc which gave a brilliant light. The ends of the carbon were heated by the current, and the arc consisted of the hot particles of carbon along which the current leaped from one rod to the other in a luminous thread of fire. Although the melting-point of carbon is 3,600 degrees Centigrade (6,472 degrees Fahrenheit), it cannot stand up very long under a heat which breaks down its structure and, at times, even fuses it. The globes which were placed around the glowing carbons were open at top and bottom and, although they steadied the flame, they did not in any way prevent the carbons from dropping to pieces under the heat generated by the current. Nevertheless, the Brush electric arc-lamp justified itself as a means of outdoor lighting and was soon seen in the streets, over shops, and in large buildings. In Cleveland, in Akron, Ohio, and many of the cities of the Middle West, lofty poles and masts were erected from which the rays of the new light were spread over wide areas.

Numerous methods, none of them practically successful, were devised for shutting off the oxygen supply from the carbons, such as by closing the globes at both ends and by regulating the movements of the carbon by mechanical aids. Once the oxygen in the globes was consumed, the waste of the carbons was considerably less. By mixing other substances with the carbon base, rods were produced which gave more light and also attractive variations of color. As every material burns with a color of its own, some striking hues in lights were seen. Thus arc-lights took on warm, yellow tinges, or seemed blue. These "flame arcs," offered in many different forms and accompanied by fanciful descriptions, reminded one of the eloquent prophecy of Winsor, the original gas showman.

Charles P. Steinmetz, a young German of the earnest, industrious type, fled to this country because his socialistic views had embroiled him with his government. After he arrived here he began by working as a day-laborer on a farm. Eventually

he became chief engineer of the General Electric Company and one of our greatest experts in certain fields of electricity. Steinmetz developed the magnetite, or so-called "luminous arc." Instead of carbons he employed for his device a piece of magnetite. This arc is now about the only survivor of its class, and its use is confined to the streets.

As metals give off a peculiar light when heated, so also do certain vapors composed of fine particles which float in suspension. Vapor-lamps began to come into use about 1861, the year in which was born a boy whose name will always be connected with them. He was Peter Cooper Hewitt, grandson of Peter Cooper, the philanthropic glue manufacturer, who founded Cooper Union, and a son of Abram S. Hewitt, a leader in the iron industry and at one time mayor of the city of New York. The wealth and the high social position of his family might have been a handicap to one less industrious by inheritance. The young man entered the manufacturing business, but later left it to conduct his own laboratory as an electrical engineer. In the tower of Madison Square Garden he set up his workshop of science, where he toiled hours into the night on his inventions.

His mercury vapor-lamp, in reality a mercury arc, consists of a long glass tube in which there is a little loose quicksilver or mercury. The air has been pumped out of the tube, which is sealed at both ends. Current is supplied by wires leading to the ends of the tube. As the current is turned on, the tube is slightly tilted. The mercury on the lower side runs into a thin thread and soon breaks. There is formed an arc, which, by its intense heat, vaporizes the fluid metal. At once the whole tube begins to glow with a luminous mercury mist. The light is of a peculiar greenish hue, which gives to the human face a ghastly look and makes the veins stand out like little purple rivers on a map. That is because the red rays are missing from the Cooper Hewitt light, and as there is no red light to reflect, the rosiest lips beneath those strange rays appear purplish. The light is in much demand in printing-offices and factories, and it will probably always have an important place in industrial illumination.

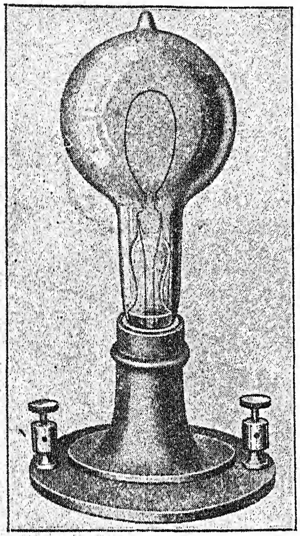
Edison and the Incandescent Lamp

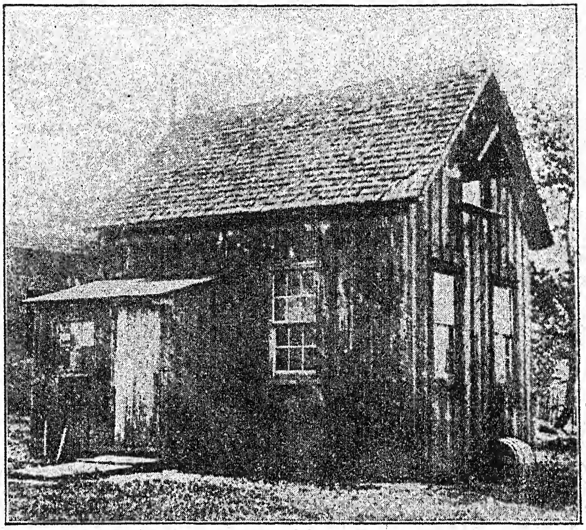
How inventive genius may be found in all walks of life, is no better shown than in comparing the careers of Hewitt and Thomas Alva Edison. Edison came of plain people who were of the pioneer stock that built up the Middle West. At the age of eleven he was experimenting with chemicals in the cellar of his father's house. From many sources he had gathered together 200 large bottles, which he marked "Poison" to keep intruders from meddling with them. Then he filled them with mixtures and solutions of his own making, obtaining the materials from the village drug-store. At the age of fifteen he was the possessor of important books on chemistry and physics, and the owner of an apparatus for his experiments. So great a drain on his scant allowance were his experiments, that he persuaded his parents to permit him to become a train newsboy. By this time the Edisons had moved to Port Huron, and the young inventor made the daily run from that town to Detroit, a distance of sixty-three miles, by the Grand Trunk Railroad. He carried his experimental apparatus with him, for in a baggage-car he had a small laboratory and also a printing-press.

From train-boy he graduated into a telegraph-operator, and thus came in touch with the powerful force of which he was to become a master. By 1877, he was well established in a laboratory at Menlo Park, near Elizabethport, New Jersey, with sufficient capital to engage assistants and to work out one of the ambitions of his life, the subdivision of the electric current.

Arc-lights were clearly too big and dazzling for the home. What was wanted was a little lamp to which a comparatively small amount of current from a main conductor could be fed, just as small gas-pipes tap large gas-mains for home gas-lighting. Contemporary scientists were quite sure that this could not be done, and they were very solemn and profound when they learned of the unusual proposal of Edison. John Tyndall, one of the most eminent physicists of England, smiled when he read of the great task which the former train-boy had set for himself, and in extenuation said that he would rather have Edison attack the problem than himself.

Progress had been made in the dynamo for the generation of a steady flow of electricity by such men as Professor Moses G. Farmer, of the University of Pennsylvania, who had devised a self-exciting type, but the electrical art was still in its swaddling-clothes. Edison proposed to use the electric current to heat some substance which would endure a high temperature





Courtesy General Electric Company.

(Left) REPLICA OF EDISON'S FIRST INCANDESCENT LAMP.
(Right) FIRST INCANDESCENT-LAMP FACTORY, MENLO PARK, 1880.

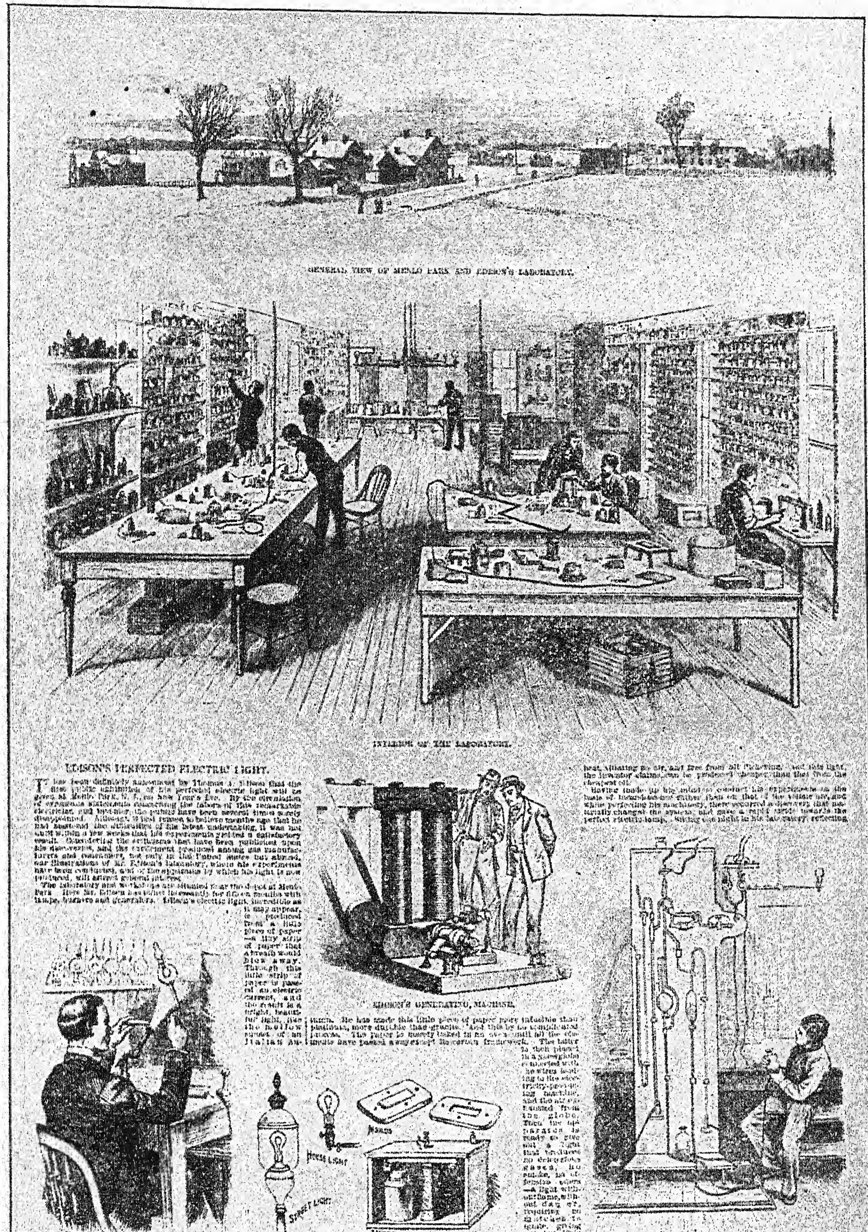
without breaking down. Heat and light have always been inseparable; the greater the heat, the greater is the light obtained. White-hot iron glows more brightly than red-hot iron, for instance. "What substance," Edison asked himself, "has the highest melting-point?" The books told him that many metals had high melting-points; also carbon. With carbon he determined to experiment. Carbon burns in the air, as every flaming match or coal fire tells us. The electric current would consume it. Then the air must be removed, so that the current would simply heat it to incandescence.

Edison began his task with a charred strip of paper mounted in a glass vessel, from which the air had been pumped out. The

first lamp thus made burned out in eight minutes. Carbon seemed unpromising. Edison turned aside to experiment with metals. His tests made him return to carbon again. He could not remove as much air as he wanted to from his bulbs because he had only a crude hand air-pump. Even after he had acquired more knowledge and skill, the best lamp that he could make would not last more than ten or fifteen minutes. It seemed as if the scientists were right in maintaining that Edison could never succeed, for the simple reason, as they theorized, that carbon contained within itself the elements of its own destruction. Once more he returned to metals. At length he succeeded in obtaining a pump that would draw out nearly all the air from a bulb, which circumstance had the effect of causing him to take up carbon again. He succeeded, in 1879, in carbonizing or partly charring a cotton thread in such a way that, when placed in a globe, from which the air was pumped before it was sealed, it glowed for forty hours in succession. It was the first practical incandescent electric lamp.

"We sat and looked," said Edison later, "and the lamp continued to burn. The longer it burned the more fascinated we were. None of us could go to bed, and there was no sleep for forty hours. We sat and just watched it with anxiety and growing elation. It could not be put on the market, but it showed that electricity could be used for incandescent lighting. I spent about $40,000 in bringing the investigation up to that point, and yet in a way this was only the beginning."

His first successful demonstration of the new light on a large scale was with carbonized strips of paper which he put in several hundred lamps used in lighting his laboratory and house, and some of the streets in Menlo Park. The result was so good that on December 31, 1879, the *New York Herald* had a page article about the wonderful and novel light, due to the passage of electricity through a scrap of paper. Shortly after that Edison, who had become known as the "Wizard of Menlo Park," gave a public exhibition of the new light source in the presence of 3,000 persons, who had been brought on special trains from New York to witness it. Before they came they may have entertained some doubts as to the practicability of the system, but they had none when they left.


GENERAL VIEW OF MENLO PARK AND EDISON'S LABORATORY.

INTERIOR OF THE LABORATORY.

EDISON'S PERFECTED ELECTRIC LIGHT.

EDISON'S GENERATING MACHINE.

From "Harper's Weekly" (1882), *by courtesy of New York Edison Company.*

THE BIRTHPLACE OF THE INCANDESCENT LAMP.

cenes in Edison's Menlo Park laboratory, where the first experiments in electric incandescent illumination were made between 1879 and 1885.

Edison, however, was anything but satisfied with these paper-carbon lamps. They would break down because the carbon was not of the right kind. But what was the right kind? In their authoritative life of Edison, Dyer and Martin state that Edison tested no fewer than 6,000 vegetable growths. "He began to carbonize everything in nature that he could lay his hands on. In his laboratory note-books are innumerable jottings of the things that were carbonized and tried, such as tissue-paper, soft paper, all kinds of cardboards, drawing-paper of all grades, paper saturated with tar, all kinds of threads, fish-line, threads rubbed with tarred lampblack, fine threads plaited together in strands, cotton soaked in boiling tar, lamp-wick, twine, tar and lampblack mixed with a proportion of lime, vulcanized fibre, celluloid, boxwood, cocoanut hair and shell, spruce, hickory, baywood, cedar and maple shavings, rosewood, punk, cork, bagging, flax, and a host of other things."

Eventually one hot day when the inventor was walking about his laboratory, he noticed and picked up a palm-leaf fan. Seeing that the edge of it was bound with a strip of bamboo, he tore off the strip.

"Test that," he said to one of his men.

The test proved that this variety of bamboo was the best material that he had thus far discovered. He found that it came from Japan. Would some other tropical fibre be still better? He must find out, even though the world must be ransacked. He sent out men to explore the tropics for grasses and fibres. One man was despatched to China and Japan to collect specimens; another was posted off to South America to explore 2,000 miles of Brazil's unknown interior; a third expedition combed Cuba and Jamaica; Ricalton, a school-teacher, was engaged to find what he could in Ceylon, India, and Burmah; one man, Frank McGowan, explored Peru, Ecuador, and Colombia, faced hostile Indians and beasts of prey, endured the stings of insects, tasted no meat for four months, wandered about for ninety-eight days without removing his clothes, and braved perils comparable only with those faced by Richard the Lion Heart and his crusaders. Bales and bales of fibres, bamboos, grasses were shipped back to Menlo Park. Death itself was faced to satisfy the eager, restless mind that dominated

the laboratory. In the end the Japanese bamboo still proved to be the best. One hundred thousand dollars was spent in satisfying Edison's desire to discover the very best natural fibre that could be carbonized to produce a lamp filament.

Upon Edison rested the burden of doing for the current what Clegg had done for illuminating gas. There was no such thing as that now familiar structure, a central lighting-station or power-house. The installation at Menlo Park was only the crude beginning of a system. The first central lighting-station in the country was the one which Edison built, in 1881, at 255 Pearl Street, New York city, in an old building which was in reality only a shell. The floors would not sustain the weight of the dynamos; so an iron and steel framework was built, on which the apparatus was installed.

Many were the anxious days and nights spent at this pioneer plant. The engines which drove the dynamos were continually getting out of order, the dynamos behaved like creatures set free from the circus, and now and then dire tales were brought in about horses going wild in the streets, as they stepped on ground alive with runaway current. Through the watches of the night Edison often slept on piles of iron conduit in the cellar, glad to snatch a few minutes of rest before again tackling the hard problems of distribution. The inventor himself was the life and soul of that prototype of thousands of central stations now running, as if by clock control, throughout the world.

In his well-appointed offices in the old Bishop mansion at 65 Fifth Avenue, Edison had been conferring with the financial powers of the country who were forwarding his inventions. There he had shown to them his plans for the Pearl Street station, and very well they looked on paper. But in the actual dust and grime of Pearl Street a hundred troublesome details crowded upon him at once. The measuring of the current used in illumination was an economic puzzle for which he had to perfect a meter, just as Clegg had done for gas. J. Pierpont Morgan was interested in industrial lighting, but from the banking-house he directed came a demand as to what the new company meant by overcharging for electric light. Edison, as meter-reader, adjuster, and general utility man, went down to the offices at Broad and Wall Streets and found that there was

nothing at all the matter with the meter, and proved it to a mathematical nicety.

After the technic for a central station had been developed, Edison worked out a plan for distributing the current through wires drawn through conduits, a process which involved not only professional but political skill, owing to the opposition of certain factions in city governments. The General Electric Company at Schenectady, New York, and at Harrison, New Jersey, took over the making of dynamos and other forms of light-bringing apparatus, and lamps were turned out by the thousands. Companies were formed throughout the country for the distribution of the current for illuminating purposes.

Meanwhile experiments for the improvement of the lamp itself continued. The filaments of the first incandescent lamps were not uniform, and therefore varied considerably in burning. Finally Edison adopted a method which proved more satisfactory, at least for a time. A thick solution of gun-cotton, which had been denitrated, that is, robbed of its explosive quality, was squirted through fine holes in a plate of platinum. The threads were dropped into an alcoholic bath which hardened them. When the fibres had been hardened they were not unlike fine catgut. This process, much the same as that employed in making artificial silk, is the principle that the spider uses in spinning its web.

Modern Research in Electric Lighting

With the development of the squirted filament, Edison left the further improvement of the incandescent lamp to the General Electric Company. A research laboratory had been established at Schenectady, New York, at the head of which was placed Doctor W. R. Whitney, a distinguished chemist. Light was henceforth to be studied from the standpoint of both the pure and the applied scientist. It was the purpose of the laboratories under Doctor Whitney's direction to make the improvement of the incandescent lamp as much an organized business as the manufacture and selling of lamps themselves. Chemists and physicists were hired to make investigations, each man conducting experiments which would add a little to the sum total of human knowledge, even though no great invention

was necessarily involved. Henceforth team-work rather than the flashes of solitary genius was to bring new lamps into being.

An accident gave the laboratories their first great opportunity. It had been found that if carbon filaments were packed in graphite and baked they glowed better in a bulb. These were called "treated filaments." One day a shipment of treated filaments was tested in the laboratories. They glowed with

(Left) DOCTOR W. D. COOLIDGE.

Doctor Coolidge discovered the process of converting brittle metallic tungsten into a ductile metal, which is now used for the filaments of incandescent lamps.

(Right) DOCTOR IRVING LANGMUIR.

Doctor Langmuir developed the modern gas-filled incandescent lamp.

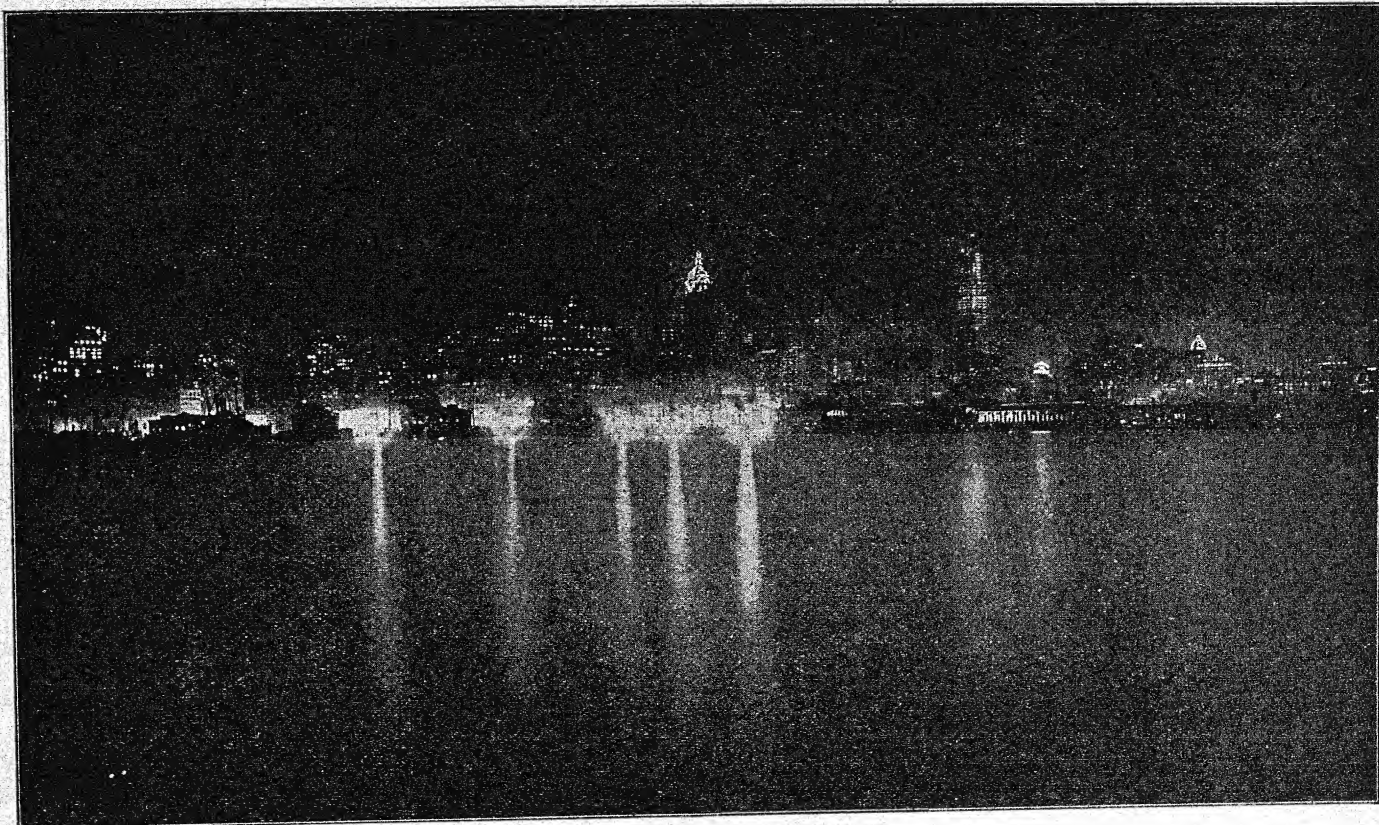
astonishing brilliancy and consumed less current than had ever been noted before. Why? An investigation was made. It was found that by mistake a workman had baked a batch of filaments *twice*. Thus was born what came to be known as the "Gem" lamp, which had its vogue fifteen years ago, but which has since been superseded by more efficient lamps. It is historically important, however, because it was the last of the carbon lamps.

One of the most eminent of the many highly trained physicists and research workers in the General Electric Company's

works at Schenectady is Doctor W. D. Coolidge, who became interested in tungsten as a filament for electric lamps. This rare metal, discovered in 1870, melts at 6,000 degrees Fâhrenheit, and is therefore an ideal material for filaments. As tungsten is not capable of being drawn into a thread of itself, as many metals are, it was ultimately powdered, mixed with a sticky binder, and squirted into threads which could be readily employed for the lamp. With this Doctor Auer von Welsbach and Doctor H. Kuzel of Vienna had been satisfied. Doctor Coolidge, however, in the same spirit which Edison had so often displayed, was convinced that tungsten had possibilities undreamed of. He had behind him all the resources of the laboratories. With the aid of a score of assistants he attacked the difficult problem of making tungsten in such a form that it could be hammered like iron and drawn into a thin wire. In its natural state, tungsten is as brittle as glass. It is easy to see how hopeless the problem seemed of solution. After years of work, Coolidge eventually devised a process which made it possible to mash the tungsten molecules together and make them more fibrous in structure, so that they would felt together. Thus changed, tungsten became as malleable as iron.

The effect on electric illumination was startling. The carbon filament gave light that was yellow. This new tungsten filament gave a whiter light and consumed only one-half the current per candle-power. The lighting bill of the country as a whole was reduced by millions a month.

Another chemist of the laboratories, Doctor Irving Langmuir, had been trying to discover why bulbs blacken after a time. Of course the material that clouded the glass came from the filament. But unless the actual process were known it could not be arrested. Some said that the blacking was due to evaporation; in other words that because there was a good vacuum in the bulb the filament gradually boiled away. Others said that undivined chemical processes were at work. To clear up the point, Langmuir began a purely scientific investigation. He found that in truth the filament did boil away. It so happened that he had also been studying the radiation of heat from thin hot wires—a study that might make it possible to produce not only better filaments but also, for example, better electric

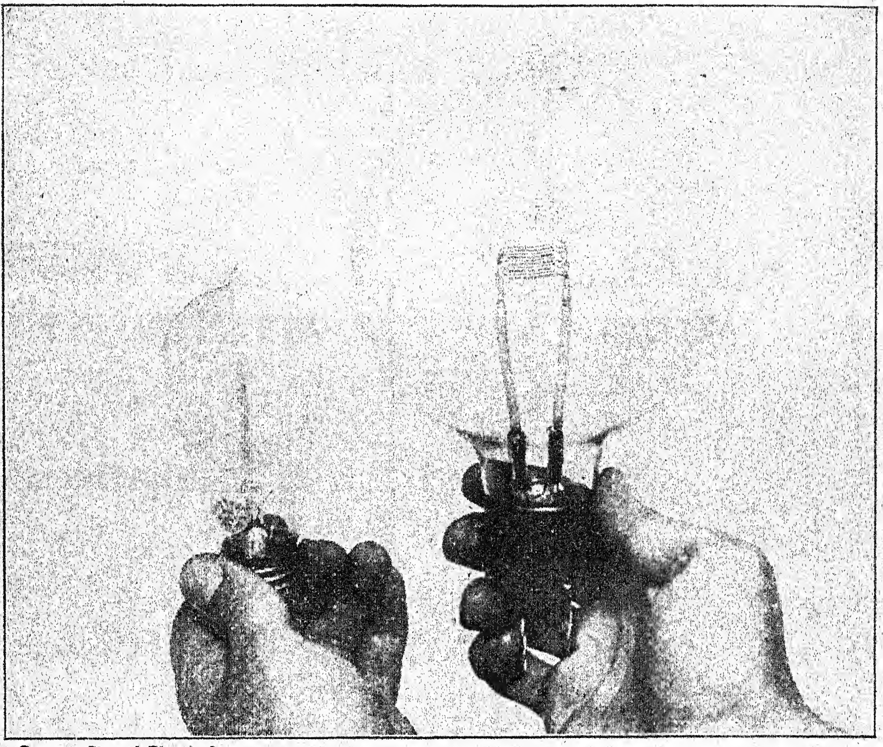


Courtesy New York Edison Company.

MORE ARTIFICIAL LIGHT THAN THERE WAS IN ALL AMERICA A CENTURY AGO.

The inventions of Edison, Coolidge, and Langmuir have made electric incandescent lighting so cheap that the country as a whole requires 9,000,000,000 candle-power to illuminate its city streets, homes, and factories.

toasters. Langmuir discovered entirely new laws. Curiously enough the investigation of bulb-blackening and the investigation of hot wires yielded results that dovetailed. He saw that



Courtesy General Electric Company.

THE SMALL LAMP IS A MODERN VACUUM TUNGSTEN-FILAMENT LAMP; THE LARGE LAMP IS OF THE GAS-FILLED TYPE.

it might be possible to make a lamp even more efficient than that invented by Coolidge.

To stop the filament from boiling away and blackening the bulb, pressure had to be applied; the pressure of a gas. It must be a gas that would not chemically combine with the filament to disintegrate it, as oxygen combines with iron to produce rust. Nitrogen was such a gas. Edison had tried it years before, but unsuccessfully. Langmuir found that the filament would have to be thick if any great amount of light were thus to be produced. But Edison had conclusively demonstrated

that the filament must be thin in order to obtain the greatest heating effect with the least possible amount of current. How could a filament be at once thick and thin? Langmuir simply took a thin filament of tungsten and coiled it into what is called a helix, and thus reconciled the irreconcilables. His helix, considered as a mass, was thick, and yet it was nothing but a thin wire. In the atmosphere of nitrogen the helix glowed marvellously. Again more light was obtained for less money per candle-power. Astonishing as it may seem, Langmuir worked out his nitrogen lamp on paper before he ever made one, and predicted exactly what its performance would be.

Ductile tungsten and the nitrogen bulb give about three times as much light for the money as the old carbon filament gave. If we were dependent on the carbon filament to give forth the 9,000,000,000 candle-power now used in this country, our power-houses would have to burn 35,000,000 tons of coal a year as contrasted with the 10,000,000 tons which now answer the purpose.

The final development of the incandescent lamp has given to us a Broadway which is a blaze of light and color. A century and a quarter ago the average home had about fifteen candle-hours a night, or about five of the old-time moulded candles, each of which was lighted on an average of three hours before the family went to bed. Now, the home may have 1,000 candle-hours of radiance for the price once paid for five tallow tapers.

It is, indeed, a wonderful pilgrimage which our light-bringers have made from the burning rush, the greasy lamp, and the first gas to the brilliantly illuminated rooms and streets of the twentieth century. Take off the chimney of the ordinary kerosene-lamp and we are back in Cæsar's day. Turn on a switch and we are in a garden of Aladdin. Thus the pressure of a finger has enabled us with the aid of the genii of science to trade our old lamps for new.

What next? Perhaps that final wonder, light without heat, such as the glowworm gives.